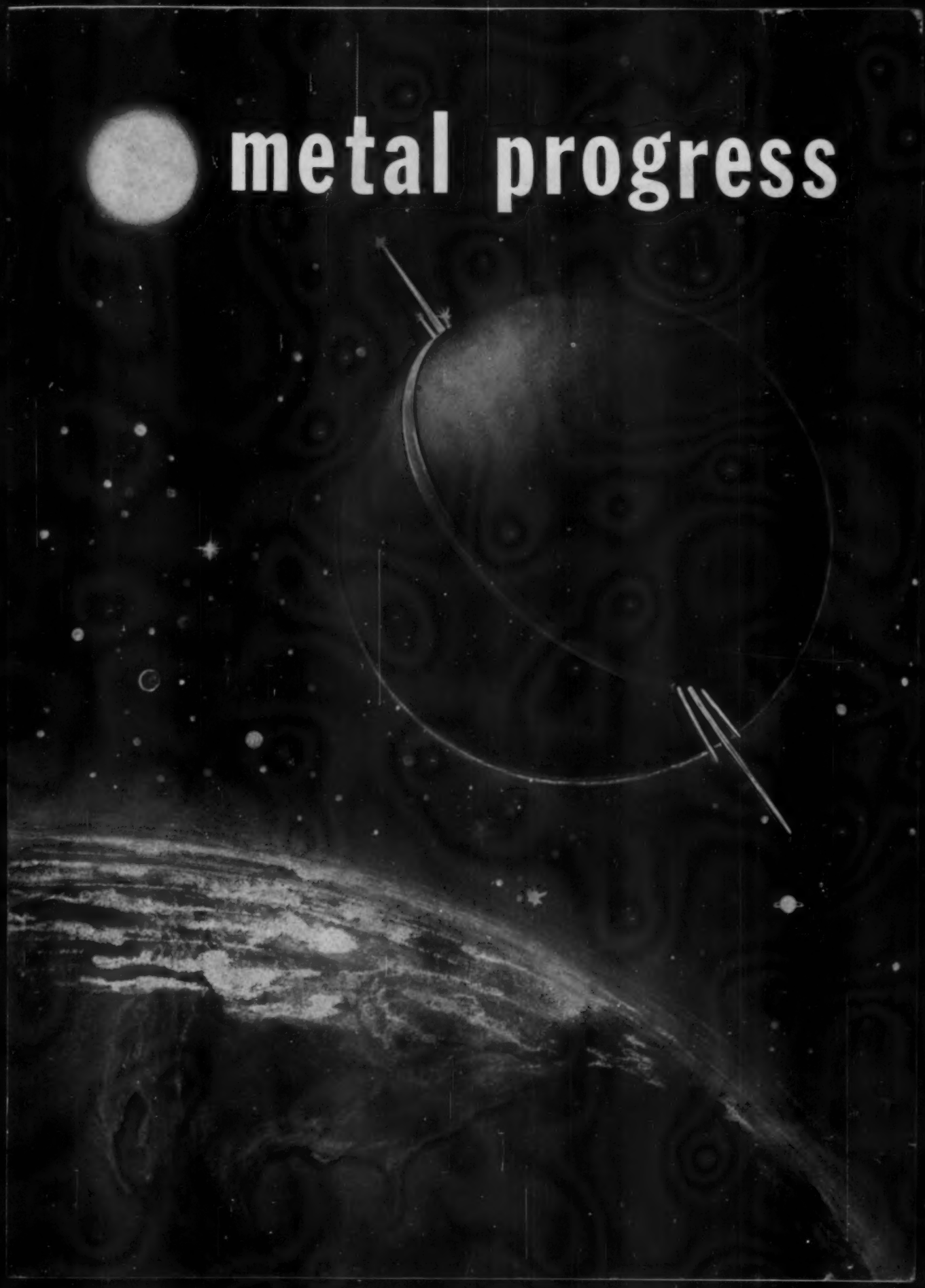
metal progress



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Metal Progress

Volume 71, No. 5

May . . . 1957

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The satellite design on the front cover was executed by ROBERT L. SCIPIONE as an entry in the 1957 cover competition at the Cleveland Institute of Art

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Metals for Fast Flight 65

Many sessions of the Western Metal Congress in March discussed metals for airframes, not alone for those going twice the speed of sound, which we have now, but strong enough for the 2400 mi. per hr. anticipated in 1970. The latter is unknown at present. Even the alloys which nearest approach it are so intractable that entirely new fabrication techniques will have to be developed. (T24a, SGA-h, SGB-a)*

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Age hardenable stainless may require complex and precise heat treatments for optimum properties. When mill annealed strip is rolled to hard or half-hard temper it has fair formability and age hardens to higher strengths during a simple reheating. (Q23q, J27d, 3-18; SS)

Hardenability Test for Deep Hardening Steels, by Carl L. Carman, Dominick F. Armiento and Harold Markus 77

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Formation of sigma phase in high Cr-Ni alloys of iron is usually blamed for embrittlement of the alloys after long heating, but there is reason to believe that some more subtle phenomenon is also a contributing factor. (N8, Q6n, 3-18; SS)

Atmospheres for Sintering Furnaces, by N. K. Koebel 91

Powder metal compacts consist of such tiny fragments – have such large surface-to-mass ratio – that sintering must be done in highly protective atmospheres. These are generated in the same types of equipment as installed in modern heat treating departments. (H15q, 1-2)

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In his introduction to the conference held by Albuquerque and Los Alamos Chapters, General Canterbury notes that stainless steels are needed for sustained flight above Mach 3.3 that cermet turbine blades are required for engines and the only reason we can build rockets is that their life is measured in seconds. (T24; SGA-h, SGB-a)

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METAL PROGRESS is published monthly by the AMERICAN SOCIETY FOR METALS. Publication office, Mt. Morris, Ill. Editorial, executive and advertising offices, 7301 Euclid Ave., Cleveland 3, Ohio. Subscription $7.50 a year in U.S. and Canada; foreign $10.50. Single copies $1.50; special issues $3.00 . . . The A.S.M. is not responsible for statements or opinions in this publication.

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As I was saying...

IT'S JUST GREAT to get back to the West where I spent some time during my scholastic days – spread over a period of seven years. When I gave up the idea of further and more advanced education and started as principal of a high school in Kansas, I still had a longing for the land of the setting sun.

My present pleasurable work brings me west with greater frequency – and how I enjoy seeing my western friends! Heading this column with me is my faithful friend and golf advisor Tom Hutton of the Golden Gate Chapter, who has been a go-getter founder of the Golden Gate, Los Angeles, and now the Santa Clara Valley Chapters. Tom represents a number of important steel companies and I am just one of his millions of friends, and I consider myself mighty lucky to be among that group.

The charters of the Santa Clara Valley and San Fernando Valley Chapters were presented by President Don and the Secretary last month. I spoke first (to survey the audience and let the President know if there were any ladies present and if we should give lecture A or B) and when talking at the Santa Clara meeting in Palo Alto I got all wound up telling about the wild life of the student – no, not students but animals – when I was at Stanford; and when I got going on all 16 cylinders, Don came very close to having no time left at all but made the statement, "I want to thank you for the fine attention you gave the Secretary and I will come back again at some later date and give my talk."

By the way, enrollment in Stanford's metallurgical department has more than doubled – all because they now give a two-hour course on "Introductory Metallurgy" for the freshmen. It is popular and fills the metallurgy classes from that time on. (I just learned that Wisconsin University does the same and has also doubled its enrollment.) More power to the two-hour met courses!

Some of these days the A.S.M. should have a slogan to promote metallurgy (and the A.S.M. also). We all know "Progress is our most . . .", "You can be sure if . . .", "Better life through . . ." No more thinking about it than up comes A.S.M.'s well-known and beloved pioneer, Horace Knerr with the suggestion "Security and Progress through Metallurgy". So here we go – let's have your reactions and suggestions.

Just a few highlights from the Western Congress and Show: best program ever by A.S.M., I.H.E.A., A.W.S., S.N.T., A.I.M.E. (Metals Branch); Titanium Conference sold out – more than 150 enrolled; Expo largest ever, best attendance (73,342), highly satisfied exhibitors; wonderful weather; 800 at Moulin Rouge dinner; hotels packed; everybody happy; all a great success!

Thanks to all participants and to the fine cooperation of the Los Angeles Chapter and the Western Divisions of 35 national technical societies.

Next Western Show will be in Los Angeles at Pan-Pacific, March 16 to 20, 1959.

So long now, Cordially,

Bill

W. H. Eisenman, *Secretary*
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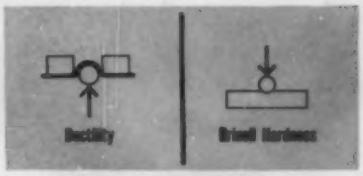

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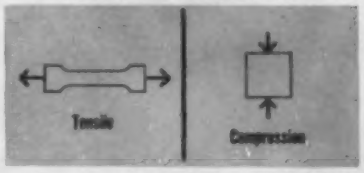

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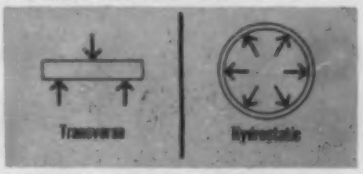

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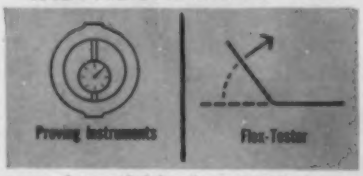

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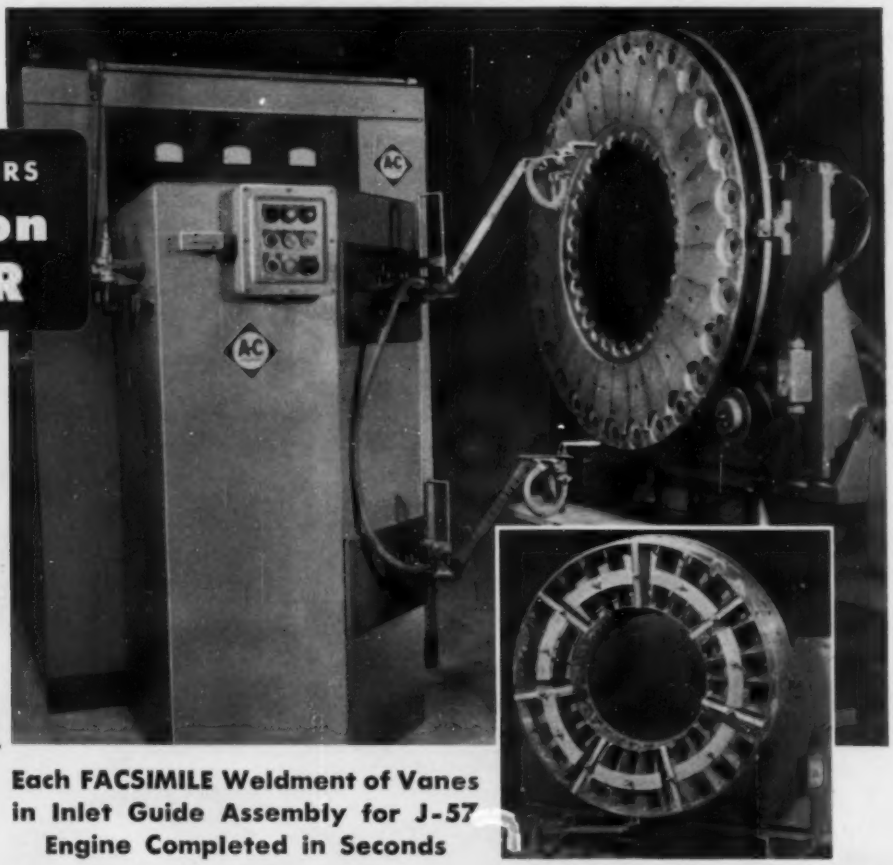

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Tool Steel Topics

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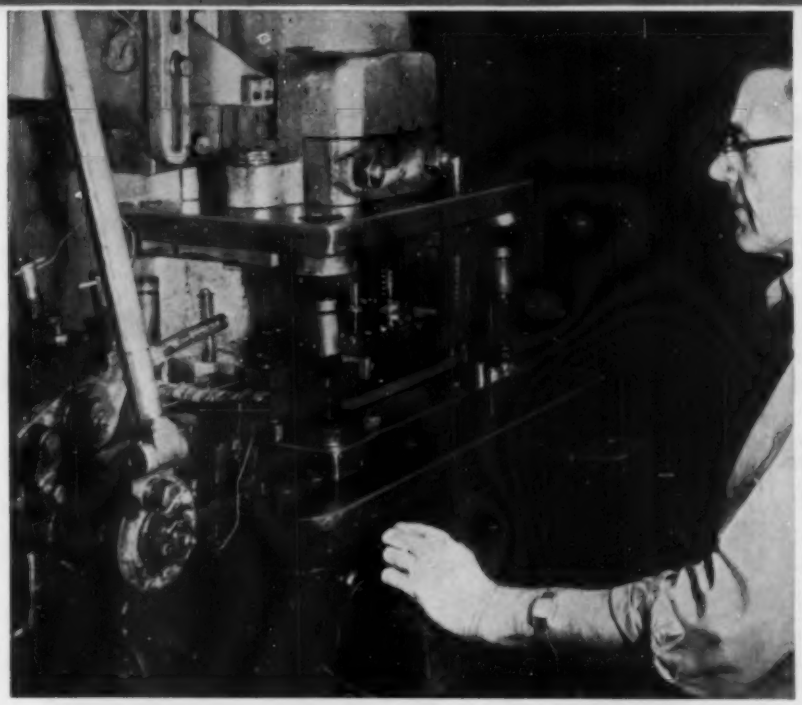

Lehigh H does good job in blanking-and-forming die

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If a number of light cuts are taken, with intervals between cuts to prevent building up temperature, the grinding cracks can be removed, so long as the tool has been properly heat-treated. But if ordinary grinding technique is used, the cracks will enlarge ahead of the grinding wheel, and ultimately will go all the way through the section.

Magnetic-powder testing is required for examination of the tool during the salvage operation, in order to determine when the cracks have been removed. If grinding cracks are detected before a tool is used (this requires magnetic-powder testing in most instances), salvage is usually successful. But should a tool be put in service with undetected grinding cracks, salvage may be impossible because of growth of the cracks in service.

cTc*...

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Unnoticed by most . . . taken for granted by those who live by its warnings, the searchlight signal of cTc — Centralized Traffic Control — stands guard on railways stretching from coast to coast. In bustling terminals . . . at lonely prairie crossroads, Seymour "PHOSPHOR BRONZE" helps these unfailing sentinels flash the stop and go messages which control our rail-borne commerce. Contact springs, connectors and other parts of their electric nerve system are formed from this corrosion-resistant, even-tempered, long-lived and reliable metal.

Seymour "PHOSPHOR BRONZE" — identified by its *Elephant Brand* — is a basic material in unnumbered applications where the strength, beauty and versatility of the finest bronze is a special requirement.

Want more information about cTc and Seymour "PHOSPHOR BRONZE"? Just write . . .

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Perfect for the job!

VANCORAM EXOKROM®

Exothermic Ferrochromium Alloy

Vancoram EXOKROM is the result of years of concentrated research and development in the laboratory, pilot plant and in the field. It is ideal for the production of low-alloy chromium steels used in hundreds of constructional applications.

Low cost and high chromium recovery with a minimum of objectionable fumes and flames are some of the outstanding qualities of EXOKROM.

Addition is easy. It is done right in the ladle. Vancoram Exokrom is packed in readily identified cans containing 25 lbs. of chromium, and cans are packed in crate-pallets for easy handling. Weighing and measuring are eliminated. Where large heats are treated, the complete pallet load can be placed in the ladle.

For more facts, call your nearest Vanadium Corporation office. Or write us today.

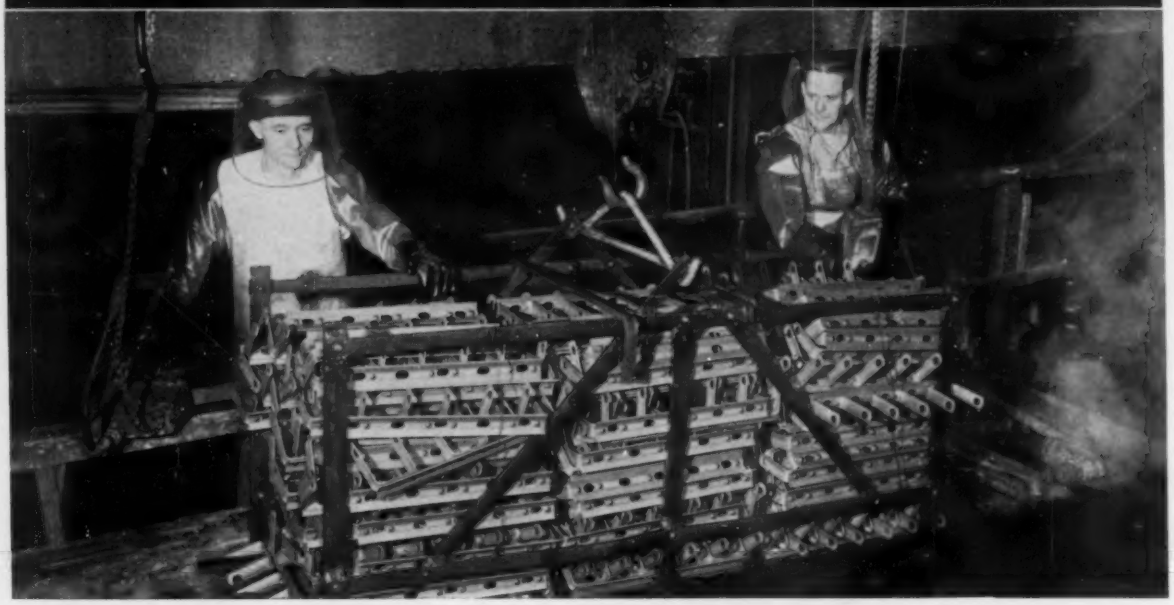
Visit us at AFS Engineered Castings Congress, May 6-10, Hotel Sinton, Cincinnati, Ohio

VANADIUM CORPORATION OF AMERICA

420 Lexington Avenue, New York 17, N. Y. • Chicago • Cleveland • Detroit • Pittsburgh

Producers of alloys, metals and chemicals

How's this for corrosion control?



Carpenter Stainless No. 20 pickling rack still in H_2SO_4 service after 5½ years!

Steady exposure to 5-15% sulphuric acid at temperatures up to 200°F for over 5½ years is the service record of this pickling rack made from Carpenter Stainless No. 20. It supports heavy loads of pole line hardware during pickling. Dependable corrosion resistance in the steel is invaluable.

Ordinary steels lasted but a short time on this application. Then, Carpenter Stainless No. 20 was put to work. The result is added safety for the workers, substantial savings in replacements, and uninterrupted production.

Today industry is finding a host of uses for this super corrosion-resisting steel. A wide variety of products of No. 20 can be purchased already fabricated . . . or you can build your own. In addition to hot sulphuric acid, this unique steel resists attack by a long list of other corrosives.

Whatever your corrosive application, talk to Carpenter first about the cost-saving advantages of No. 20. Over 70 years' experience in the development and manufacture of specialty steels are at your service when you contact your nearest Carpenter Mill-Branch Warehouse, Office or Distributor.

Partial list of Stainless No. 20 products now being fabricated:

- Agitating equipment
- Baskets
- Centrifugal pumps and parts
- Coils
  - Heating and cooling
- Dehydrators
- Exchangers, Heat
- Fans
- Fastenings (all types of standard and special design)
- Fittings
- Grommets
- Hangers
- Instruments
  - Heat and temperature
  - Industrial liquid level
- Mixers
- Nozzles
- Pails for sulphuric acid
- Pipe
- Processing equipment (food and chemical industry)
- Pump parts
- Screws
- Tanks, welded
- Thermocouple wells
- Tube
- Valve parts
- Valves
- Vessels, welded
- Weld rods
- Wire
  - Baskets
  - Cloth
  - Stranded
- And others

Carpenter Stainless No. 20-Cb is available from The Carpenter Steel Company, Alloy Tube Division, Union, New Jersey, in the forms of tubing, sheet, strip, pipe and plate; and Stainless No. 20 in the forms of bars, billets and wire.

Our new leaflet "*Positive Protection*" has a more complete list of available products made from No. 20. If you haven't a copy, please drop us a line.

Carpenter STEEL

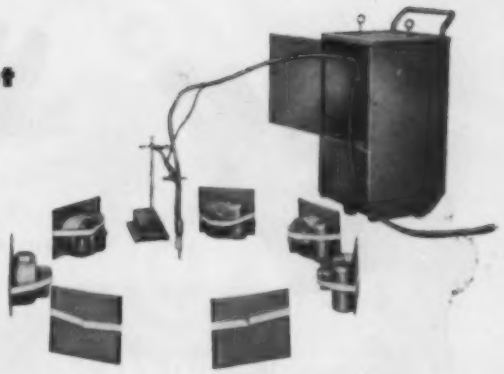
Super Corrosion-Resistant Stainless

Pioneering in Improved Tool, Alloy and Stainless Steels Through Continuing Research

The Carpenter Steel Co., 133 W. Bern St., Reading, Pa., Export Department: Port Washington, N. Y.—"CARSTEELCO"

some people have queer notions about

RADIOGRAPHY WITH ISOTOPES



Here's a typical multiple-specimen setup . . . seven castings radiographed simultaneously with a T.O. model 402 panoramic Cobalt 60 unit.

Many a plant, uneasily aware that it is missing the profits of radiographic inspection, still holds back for one mistaken "reason" or another. Here are some we run into . . .

"out of my league" . . . *costs too much*

Not so. An iridium 192 machine costing as little as $1700 may be fully adequate to your needs. *Indeed, average equipment cost is less than $2500.*

needs a *specialist* to run

On the contrary, a practical on-the-job training course in our Cleveland laboratory (free tuition to buyers) equips any intelligent employee with all he has to know.

takes forever to make a radiograph

Not so. You can x-ray 1" steel in 30 seconds, 3" sections in 4 minutes with the Cobalt 60 sources available today.

gamma radiographs are no good

Not so. If you use the right source for the right job you'll have no trouble getting the 2% detail sensitivity required by exacting inspection codes.

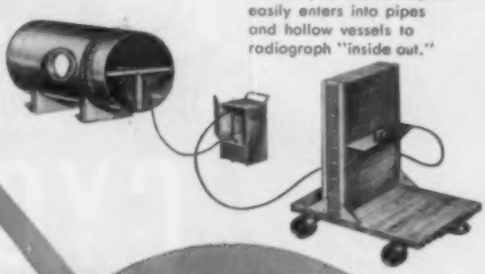
it's dangerous; we're afraid of it

No reason to be: Technical Operations modern equipment is safe and simple-to-handle.

not for me; my stuff is different

We don't know what *your* business is . . . but if *whatever* you make (or buy or sell) needs "seeing into" for quality control, radiography (either gamma or x-ray) can profit you as it does others — *your competitors included.*

The compact source capsule easily enters into pipes and hollow vessels to radiograph "inside out."



costs nothing to find out

what radiography can do for you. Simply call in your local Picker representative* or write us outlining your problem (and if possible, sending typical samples). We'll make tests and tell you frankly whether radiography holds any promise for you. Because Picker offers both x-ray and isotope equipment, we have no axe to grind for any particular method.

*There's probably a Picker district office near you (see local 'phone book)

PICKER X-RAY CORPORATION
25 South Broadway, White Plains, N. Y.

SOME OF THE TECHNICAL OPERATIONS GAMMA RADIOGRAPHY UNITS MARKETED AND SERVICED BY PICKER X-RAY

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TO402
Cobalt 60 Unit

TO404
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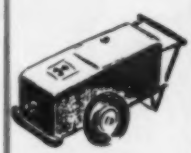

TO446
Cobalt 60 Unit

TO405
Iridium 192 Unit

TO416
Source Changer

one stop for everything in Picker x-ray **radiography and fluoroscopy**

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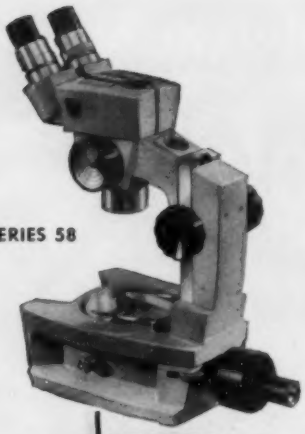

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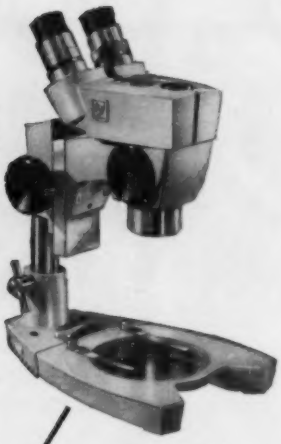

SERIES 59

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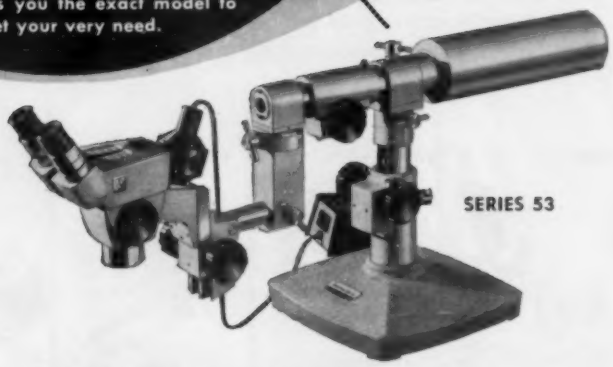

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When you use brass and aluminum in your shop bearing the unusual Scovill brand identification, you can be sure of its uniformly superior quality . . . lot after lot . . . order after order . . . made better to . . .

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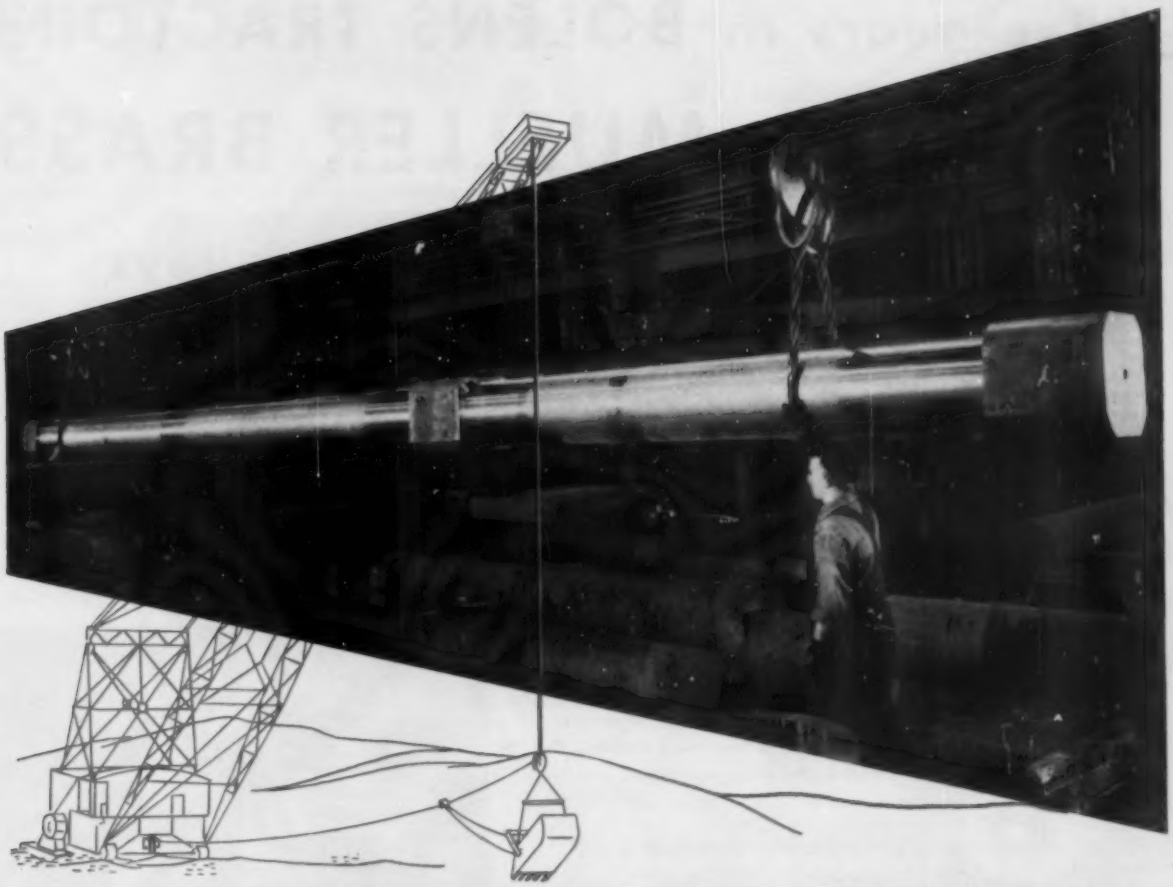

SAVE MONEY with FINKL FORGINGS

Manufacturers of earth moving equipment do!

• DIE BLOCKS • HOT WORK STEELS • ELECTRIC FURNACE STEELS • FORGINGS •

Walking draglines are ingenious, mobile monsters employed for digging and moving earth. Because of their size and applications, often in isolated areas, they must be dependable and steady in their operations. Only the best materials and workmanship will prevent costly downtime in the field.

Many of these machines employ Finkl forgings. The 48 foot "walker" shaft shown above transfers power from the engine to the walking mechanism of the dragline to move as much as 450 tons of equipment. Here the best materials and craftsmanship will prove the least expensive in the long run.

For over 78 years, Finkl has produced the best in cylinders, spindles, driveshafts, and special forgings both rough turned and finish machined. When you are considering forgings or die blocks, call your local Finkl representative.

A. Finkl & Sons Co.

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drive gears in BOLENS TRACTORS

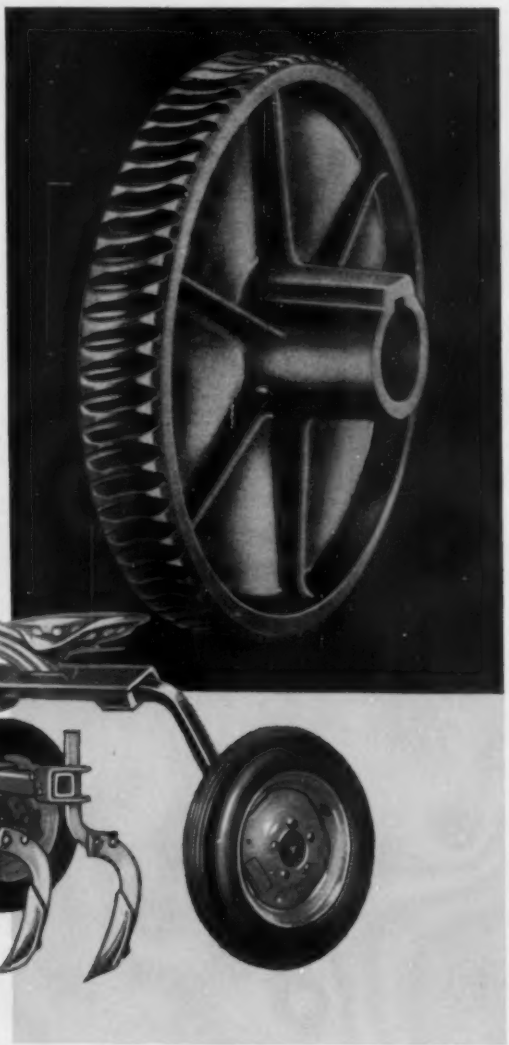
toughness of MUELLER BRASS

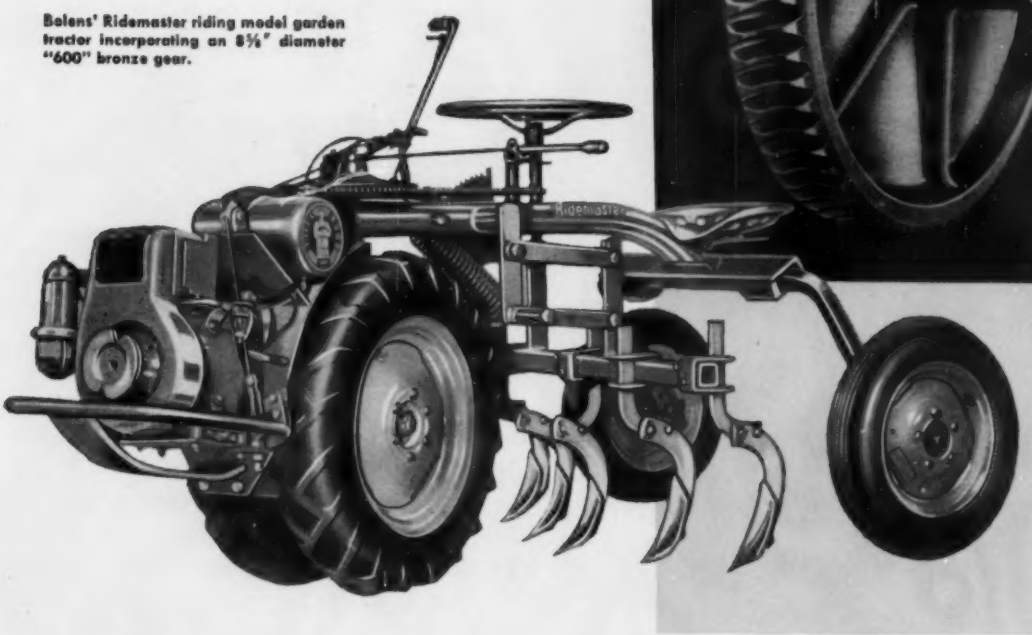
"600" series bronze alloys

Forged bronze gears made from tough, long-wearing Mueller Brass Co. "600" bearing alloy are proving their ability to withstand punishment in the popular outdoor power equipment manufactured by the Bolens Products Division of Food Machinery and Chemical Corporation, Port Washington, Wisconsin. The Junior and Super Mustang rotary tillers, all employ "600" main drive gears to dependably transmit engine power to drive assemblies. The going is rough for equipment of this type in cultivating or tilling heavy soil—but Bolens has a record for ruggedness and, on these and many other Bolens products as well, Mueller Brass Co. "600" gears help make possible that fine performance.

Mueller Brass Co. "600" bearing bronzes are available as forgings, or in rod form. They provide unusually high tensile strength, a dense structure, good resistance to corrosion, and excellent bearing properties. Because of their good machining qualities, the "600" series bronzes can be finished readily—usually at substantial savings in COST.

It will pay you to investigate these alloys for your products . . . why not write today for full information.





Bolens' Ridemaster riding model garden tractor incorporating an 8⅛" diameter "600" bronze gear.

and TILLERS prove

CO.

Bolens' Super Mustang rotary tiller incorporating a 25-tooth "600" series bronze worm gear.

• WRITE TODAY FOR THE ENGINEERING MANUAL YOU NEED

Mueller Brass Co. Forgings Engineering Manual H-58565 ☐

Tuf Stuf Aluminum Bronze Alloys Engineering Manual H-58563 ☐

"600" Series Bearing Alloys Engineering Manual FM-3000 ☐

Copper Base Alloys in Rod Form Engineering Manual FM-3010 ☐

198

40 MUELLER BRASS CO.

MUELLER BRASS CO.

PORT HURON '28, MICHIGAN

METALS AND ALLOYS REVIEW

by FRANK M. LEVY

Vice-President and Director of Research

One of the most interesting things about our 600 series bearing alloys is the great variety of products in which they find application. In the advertisement to the left you can see how the Bolens people put 600 gears to work in their rotary tillers and garden tractors. Those gears are big, take a lot of abuse, and meet the job needs perfectly. We also make a lot of small parts, too, that have been specified because of the many unusual properties of this series of alloys.

One good example that comes to mind is a shaft bushing on a rotary selector switch that we make for an instrument manufacturer. This selector is used for switching sound-powered telephone circuits aboard Naval vessels. One of the most important considerations in the choice of 600 alloy for this bushing was its resistance to abrasive action on and against a rubber "O" ring. The acceptance test required a stainless steel shaft riding in the bushing to rotate "dry" for a minimum of 50,000 cycles consisting of 360° rotation clockwise followed by a 360° rotation counter-clockwise. The "O" ring must still form a watertight seal at the end of the test. Our 602 alloy was the only one of several materials tested that met the specs. That was pretty good evidence in itself of resistance to abrasion, but, in addition, this customer also found that the use of 602 eliminated the headaches they previously had with seizing and galling.

The pounding action caused by the indexing mechanism attached to the shaft used to give them no end of seizing troubles. The chief product engineer is extremely happy about the way our alloy is performing. Mention was also made of the fact that the corrosion resistance of 602 was mighty impressive. In this application, the alloy passed the 200-hour Navy salt spray test with flying colors.

So, big or small, it seems that there is no end of applications for 600 series alloys. We even have parts working in a machine that slices frankfurters as well as gears in fishing reels. So, it seems that 600 runs the gamut from "red hots to reels". Well, it looks like the end of the page is here again, so I'll close for now. However, if you have any problems or questions about non-ferrous alloys or you're having trouble getting desired performance from a part, why not drop me a line here in Port Huron, and possibly I can be of some service. Send a part print along if you like, and we'll be glad to make proper recommendations.

Thanks again for your time.

No. 1950

ULTRASONIC CLEANER FOR METALLOGRAPHY

No. 1952 Positioning Clamp and Automet Holder

This new scientific development is ideal for cleaning metallographic specimens. It removes the hazard of carrying abrasive particles from a coarse grinding stage on to a finer grinding stage. The cleaning is accomplished quickly, thoroughly and at low operating cost. No skill is required. Additional speed and convenience is achieved by using an additional Transducer Beaker. The positioning clamp is required to accommodate the specimen holder from the Buehler Automet automatic polishing attachment.

No. 1950	ULTRASONIC CLEANER	$495.00
No. 1951	EXTRA TRANSDUCER BEAKER	$130.00
No. 1952	POSITIONING CLAMP for Automet Holder.....	$ 22.00

Buehler Ltd.

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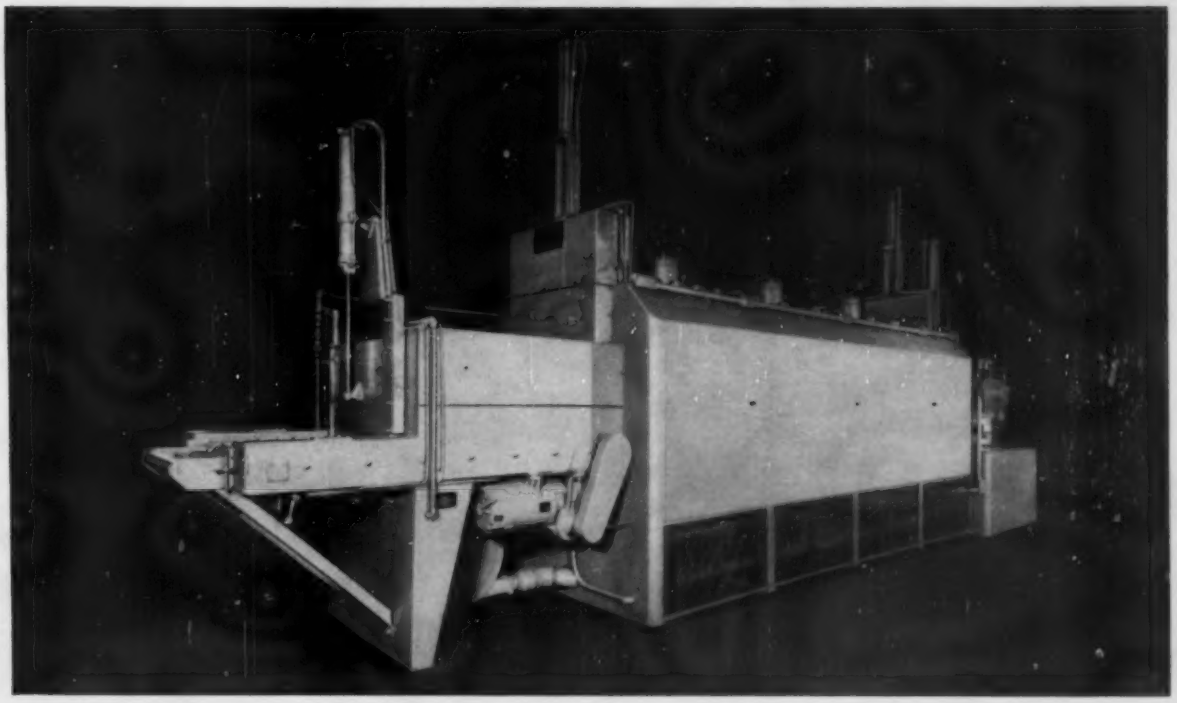

. . . for carburizing, carbo-nitriding, and general heat treating

the NEW Ipsen pusher-type furnace

Here's the new "Ipsen Pusher" . . . fully tested and proven. Check these advantages and construction features:

- **The temperature in each of the furnace's three zones is independently controlled.**

- **The Ipsen 100% forced convection heating method** combines in each zone a roof fan, sidewall baffles, and an open grid-type hearth. A centrifugal roof fan, with a water-cooled shaft, forces the atmosphere downward past the vertical radiant tubes to the bottom of the work chamber. The heated atmosphere is then forced up through a heavy open grid. Atmosphere reaches all exposed surfaces . . . whether work load is loosely or densely packed. Temperature is uniform, heating is even for all parts of the charge.

- **Ipsen Pusher furnaces can be built for either end-loading or side-loading** . . . depending on the manner in which your Ipsen Pusher Furnace is to be fitted into your production line or heat treating department.

- **A lock-chamber type purge vestibule** is sealed to the front of each furnace. This prevents outside air from directly entering the furnace work chamber to contaminate the protective atmosphere.

- **Ipsen Pusher furnaces utilize unique, straight-wall, vertical radiant tubes** . . . plus Ipsen Flame-Busters . . . both of which are made of a new alloyed ceramic material. The tubes have high strength at high temperatures. Straight-wall design eliminates possibility of burnout. When necessary, tubes can be removed vertically, in only 30 seconds, from the top of the furnace . . . no need to allow for adjacent floor space required for removal of horizontal tubes.

- **Lighter work trays . . . double chain automatic discharge:** Special silicon carbide skid hearth provides continuous and complete support of all parts of each of the furnace's six work trays. (Conventional skids or "roller" rails require trays of heavier section and greater weight.)

  When work reaches discharge end of work chamber, lugs on two continuous, parallel, cold, alloy chains (which are recessed in the hearth) move the work tray to an elevator-type quench rack . . . for controlled atmosphere cooling or automatic oil quenching.

Just published . . . Detailed information on the new Ipsen "straight-through" pusher is contained in a two-page bulletin (P-57). Ask for your copy.

IPSEN INDUSTRIES, INC. • 723 SOUTH MAIN STREET • ROCKFORD, ILLINOIS

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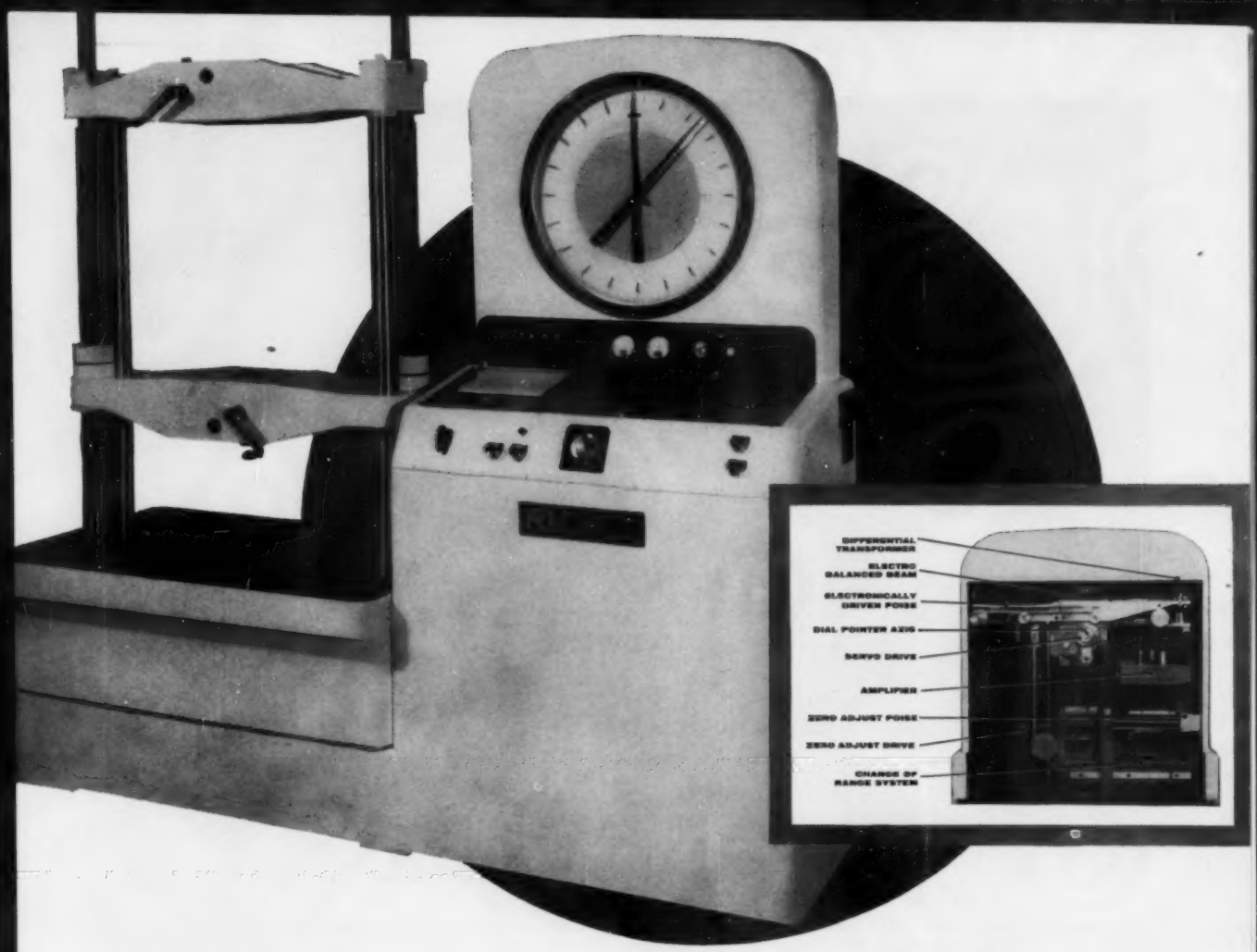
AUTOMATIC HEAT TREATING UNITS



New indicating unit makes older machines obsolete

... it's electro balanced

At last, here is the weighing system you need for today's more rigid testing. It's more sensitive — and offers quicker response — than any other system ever built. Just a slight motion at the beam end (see rear view) provides sufficient signal to operate the servo motor . . . and move the poise to establish force equilibrium.

With Riehle's new sensitivity and rapid response plus complete instrumentation, you no longer keep confirming the "errors" that present, inadequate machines may be making. It gives you full flexibility and precision in testing at elevated temperatures as well as at room temperature. The new Electro-Balanced Indicating Unit is available for both hydraulic and screw power testing machines — by Riehle. Mail coupon for Bulletin.

Riehle TESTING MACHINES

A DIVISION OF

American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

NEW BULLETIN . . . MAIL COUPON

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Division of American Machine and Metals, Inc.
Dept. MP-557, East Moline, Illinois

Please send your free 4-page Bulletin RU-14-56 with full data on the new Riehle Electro-Balanced Indicating Unit.

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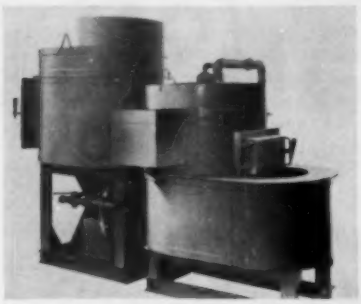
ATTENTION MR.

APPLICATION and EQUIPMENT new products

Furnaces

Cylinder-type furnaces for aluminum breakdown and holding in die casting, permanent molding and sand casting operations have been announced by Stroman Furnace & Engineering Co. The design incorporates two separate furnaces; one being the breakdown furnace and the other a



holding furnace. The furnaces are offered in a wide variety of melt rates and holding capacities, with melt rates ranging from 450 to 1600 lb. per hr., while holding capacities range from 680 to 2450 lb. Each furnace is fired with contained combustion burners, providing a mild firing condition.

For further information circle No. 1224 on literature request card, page 48-B.

Powdered Brazing Alloy

A self-fluxing brazing alloy for joining many types of aluminum alloys has been announced by Handy & Harman. This alloy, which is supplied as a dry powder and applied as an aqueous slurry, is designed for use in a molten salt bath. The alloy is painted on, and thus can be applied to any surface regardless of its contour. The brazing alloy contains its own fluxing material which serves both as a flux and as a cement that keeps the alloy in place during the brazing cycle. When the slurry is dried after application, the flux forms a cement which does not melt at the usual brazing temperatures, but which is soluble in the salt. Thus during the brazing process, the alloy becomes molten, but is held in place until the cement is dissolved. Dissolution of the cement allows the brazing alloy to fill the joint area by capillary flow. The Handy & Harman alloy is an aluminum-silicon eutectic. It melts in the narrow range of 1070 to 1080° F., and is generally brazed at a temperature of 1100° F.

For further information circle No. 1225 on literature request card, page 48-B.

Cleaning Machine

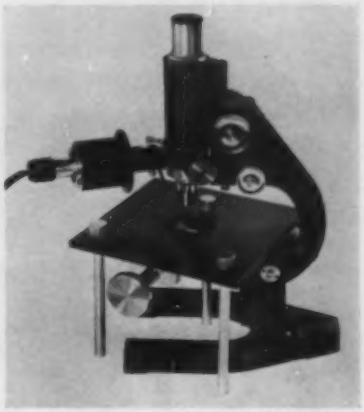
A new automatic work and tote pan cleaning machine has been announced by Ransohoff, Inc. The machine receives tote pans of work, dumps the work into a drum-type washing section, then carries the upside down tote pan through an integral conveyor-type washing section above drum section where work is processed. Both work and tote pans are washed, rinsed and dried. Tote pans return to the discharge end of the machine ahead of the parts they formerly contained. Then the clean work is loaded, automatically, into the

same tote pan. The machine can incorporate any combination of cleaning, pickling, phosphate coating and similar operations. Processes unnecessary for the tote pans or other containers can be eliminated in the conveyor section.

For further information circle No. 1226 on literature request card, page 48-B.

Strain Viewer

To provide a means for microscopic examination of metals and other solids under stress, the Harry W. Dietert Co. has announced the Flinn strain viewer. The unit consists of a specimen table with a knife-edge loading device for the transverse loading of miniature polished bar of material. The resulting plastic strain and mode of fracture can be viewed at all conventional magnifications including 1000 diam. The specimen table is equipped with three legs for use with a bench-type microscope and the legs may be easily removed if the table is

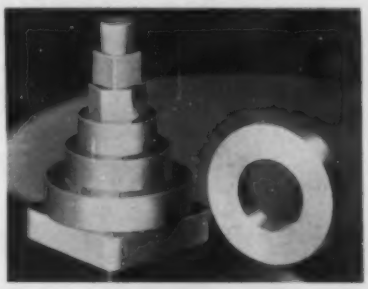


to be placed directly on the stage of the metallurgical microscope. This device, when used with a suitable microscope, makes it possible to view and photograph fracture initiation and propagation, slip, twinning and phase transformations resulting from stress.

For further information circle No. 1227 on literature request card, page 48-B.

Continuous Casting

Apex Smelting Co. announces a new method for continuous casting of aluminum alloys, known as the Apex-Goss process. Brass and copper and their alloys may also be cast by this



method. The key to the new process is an oil-lubricated graphite mold which was developed over a period of several years at Goss Laboratories in Cleveland. This mold is simple in design and operation and permits wide

What is your swaging I.Q.?

Are you aware of the new techniques and equipment that are making rotary swaging increasingly important as a basic precision production process? Test your knowledge of modern rotary swaging with this TRUE or FALSE quiz.

SWAGING is economical—no chips, no scrap . . .

SWAGING produces work accurate within ± .001" . . .

SWAGING improves physical characteristics . . .

SWAGING can produce inside contours . . .

SWAGING can be automatic or semi-automatic and does not require skilled labor for operation . . .

FENN is one of the largest manufacturers of a complete size range of swaging equipment . . .

FENN swaging equipment swages tubing up to 6¼" diameter and solid bar stock from pinpoint to 3¾" diameter . . .

If you answered TRUE to all the questions, your knowledge is excellent. If not, you should have more information on modern rotary swaging.

In either case, it will pay you to get a copy of the new Fenn Swaging Catalog No. SM56. Write today!

FENN ROTARY *Swaging Machines*

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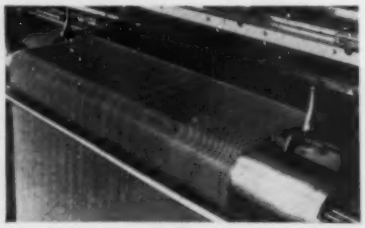
versatility in shapes produced by merely changing the mold. The illustration shows standard shapes which may be cast.

For further information circle No. 1228 on literature request card, page 48-B.

Titanium Wire Cloth

Cambridge Wire Cloth Co. has announced the production manufacture of corrosion resistant titanium wire cloth. First used by the chemical processing industry, the new titanium

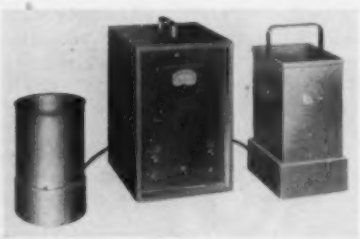


product is finding applications in filtering assemblies, catalysts, screens and other equipment. Rem-Cru Titanium's A-40 wire is used. Orders for 30 by 30 mesh, made of 0.016 in. wire and 10 by 10 mesh with wire 0.035 in. in diameter are in production.

For further information circle No. 1229 on literature request card, page 48-B.

Ultrasonic Cleaning

A new laboratory ultrasonic cleaner has been announced by Labline, Inc. It may be used for cleaning bearings,



delicate mechanisms and similar items. The unit shown can operate two cylinder tanks 6½ in. in diameter by 7 in. deep or two rectangular tanks 6½ in. wide by 8 in. long by 10 in. deep. The Labsonic cleaner is portable. Output of generator is 150 watts. Transducers are barium titanate and operate at a frequency of 35 to 40 kc. for best cleaning results.

For further information circle No. 1230 on literature request card, page 48-B.

Electrode Shipment

Gondola cars equipped with specially designed bulkheads which facilitate unloading and prevent damage to palletized graphite electrodes in transit have been announced by Great Lakes Carbon Corp. A movable bulkhead can be adjusted according to the size of the shipment.

At the opposite end of the car is a stationary bulkhead with a sliding wedge device which automatically adjusts forward to take up slack as it develops en route.

For further information circle No. 1231 on literature request card, page 48-B.

Operations Recorder

A new recorder for proving graphically when a device, machine or apparatus operates and for how long has been announced by Gorrell & Gorrell.

It is a drumtype with very slightly spiral tracing to give drum rotation at various speeds as ordered. 400 linear inches are recorded on a waterproof chart. A sharp stylus moves up uniformly ⅛ in. with each drum rotation providing the record. On 24 hr. rotation any given instant of corresponding days is easily compared since all are lined up vertically.

For further information circle No. 1232 on literature request card, page 48-B.

Resistance Welding

A three-phase frequency converter welding control has been announced by Weltronic Co. All timing, sequence and other individual functions are designed and built as individual units. These units are built on individual chassis, of the sliding drawer type, and all interconnections are made by means of a positive lock plug. The advantage in using the plug-in units is their interchangeability so that different types of welding may be performed with few changes in controls.

For further information circle No. 1233 on literature request card, page 48-B.

Tool Steel

A new tool steel in which a small amount of sulphur and a controlled graphite range bring about good machinability and finish has been announced by Allegheny Ludlum Steel Corp. By adding 0.10% sulphur to Oilgraph-EZ, which has a graphite range of from 0.20 to 0.40%, the graphite plus sulphur produce the same machinability as if the range were 0.50 to 0.70% graphite. The limited graphite particles are dispersed evenly through the steel and increase the resistance to wear and galling in service. The addition of the sulphur does not adversely affect the other properties of the steel. A typical analysis is 1.45% total C, 0.80% Mn, 1.15% Si, 0.20% Cr, 0.25% Mo, 0.10% S, 0.20 to 0.40% graphite, balance Fe.

For further information circle No. 1234 on literature request card, page 48-B.

Ovens

A new line of turbo-convection ovens has been announced by the L and L Mfg. Co. Holding heating chamber gradients within ±3° F. is possible. This low gradient is due to a combination of full muffle directed forced convection and recirculation, fan construction, powerful fan motor, controller selection, adjustable fresh air inlet and exhaust vent. There are six standard models, ranging from 225° F. to 1000° F. and in heating chamber size from 4.75 to 27 cu. ft.

For further information circle No. 1235 on literature request card, page 48-B.

Ultrasonic Testing

Branson Instruments, Inc., has announced ultrasonic thickness testing equipment to which automatic detection and recording devices may be attached. Devices will spot thickness changes as small as 0.05% and can be

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TEMPERATURES
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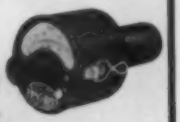

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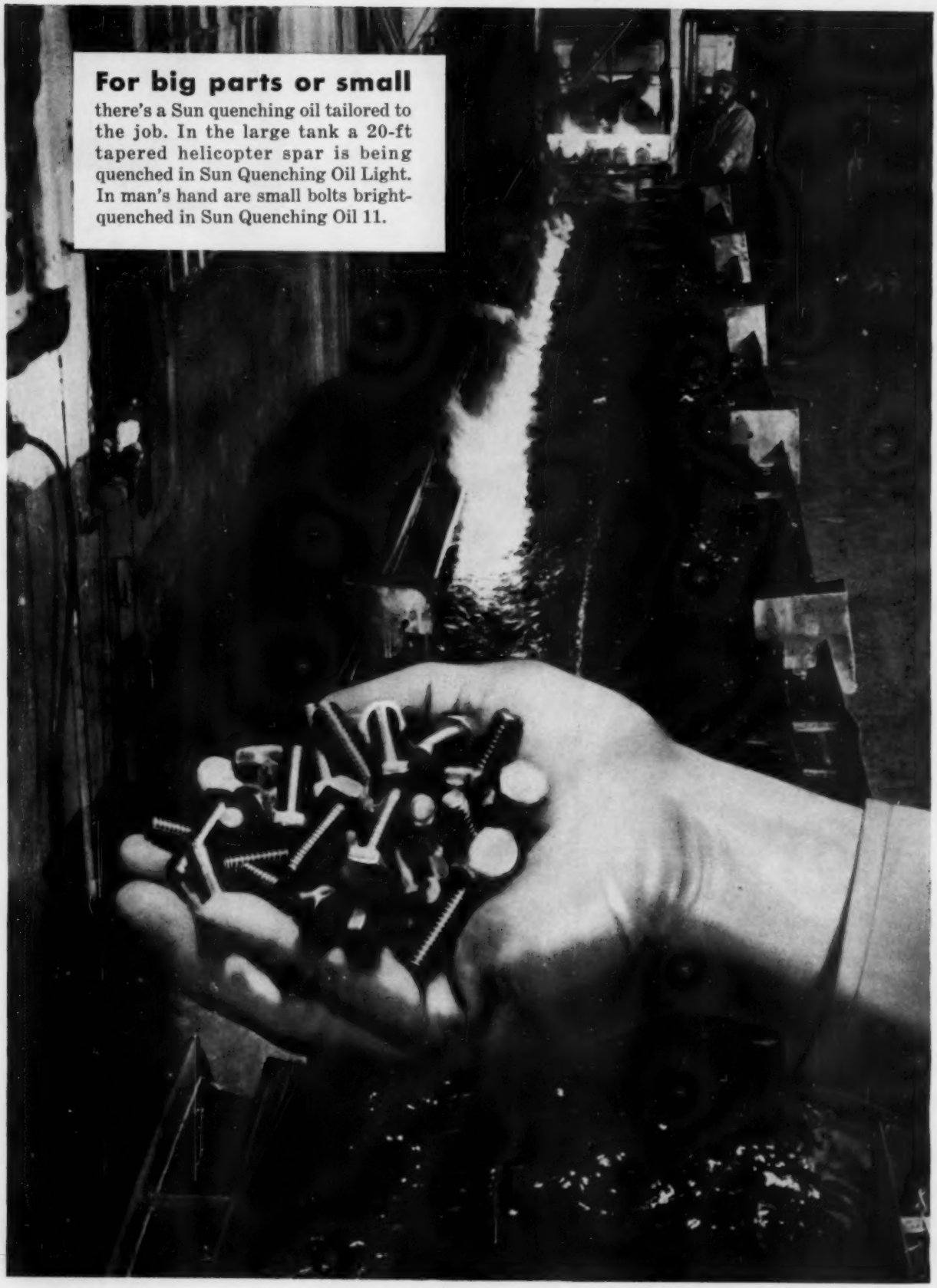

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SUN QUENCHING OIL 11 has a high flash point. Moreover, it resists breakdown at high temperatures. These characteristics make it ideal for bright quenching and for use in systems operating at above-normal temperatures.

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IN ADDITION to these three quenching oils, Sun makes several others for special applications. No matter what your quenching problem, there's a Sun quenching oil to solve it.

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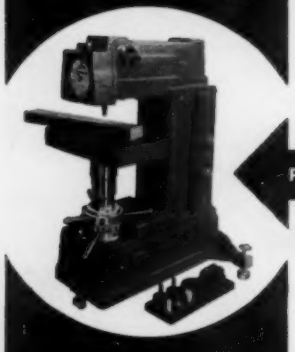

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And the FLO-METER'S ease of cleaning — 5 minutes or less, with no tools — protects the inherent accuracy of the Waukee design.

Complete information in Bulletin 203. Write for it. **Waukee Engineering Company**, 5140 North 35th Street, Milwaukee 9, Wisconsin.

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connected to ring an alarm, flash a signal light, or activate compensating controls of various sorts. The output of the gating circuit can be applied to a potentiometer-type strip chart recorder, where the deflection of the

recording pen will depend on the distance of the resonance indication from one edge of the gate. As an alternate choice, the signal, after amplification, may be used to control machining processes or to make corrective adjustments. Thicknesses down to 0.005 in. can be inspected.

For further information circle No. 1236 on literature request card, page 48-B.

Low-Temperature Cabinet

New low - temperature cabinets, ranging in sizes from 1 to 9 cu. ft., have been announced by the Hudson Bay Co. Temperatures range from ambient to —120° F., and can be re-

duced in ⅛ to 1 hr. from ambient. The unit features heavy insulated counterbalanced covers, vapor-sealed Fibreglas and cork insulation, pressure gages, oil separators and adjustable thermostats.

For further information circle No. 1237 on literature request card, page 48-B.

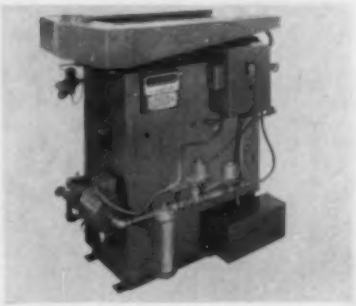
Lubricant

The development of a new molybdenum disulfide lubricant which bonds to metal without building excessive accumulation on the surface has been announced by the Alpha Molykote Corp. In Type GX the effectiveness of MoS_2 as an extreme pressure lubricant in a grease is achieved by increasing the total surface area of the molybdenum disulfide through a reduction of particle size. This permits a sharp reduction of the MoS_2 content. The decrease in particle size brings more molybdenum disulfide in contact with the metal while the reduction in solid content minimizes excessive surface accumulation.

For further information circle No. 1238 on literature request card, page 48-B.

Ultrasonic Cleaning

The Circo Equipment Co. has announced a line of seven standard ultrasonic cleaning machines. They are electrically welded and fabricated from zinc metallized heavy gage steel or stainless steel. They have a removable cleanout door and steam, electric or gas fired heating elements. High peak level of ultrasonic energy is transferred to the cleaning chamber



through stainless steel encased barium titanate transducers. At an operating frequency of 40 kc., maximum cleaning or cavitation results with a minimum energy input.

For further information circle No. 1239 on literature request card, page 48-B.

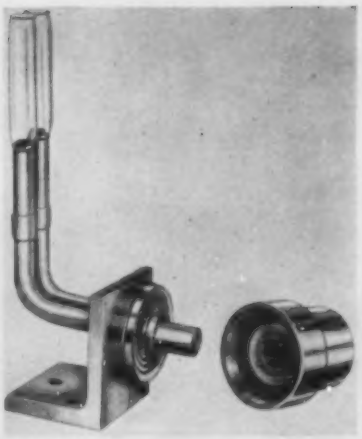
Die Casting Machine

A 1200-ton aluminum die casting machine has been announced by Lester-Phoenix, Inc. The frame is being made by Maschinenfabrik Weingarten, Germany, and the balance of the components at the Lester-Phoenix Cleveland plant. Total weight of the machine will be 170,000 lb., maximum shot capacity 40 lb., plunger stroke 25 in., die opening 36 to 10¼ in. and maximum die height 50 in.

For further information circle No. 1240 on literature request card, page 48-B.

Vacuum Valve

A new laboratory ultra-high vacuum valve for handling pressures of 10^{-10} mm. Hg and lower has been announced by the Rochester Div. of Consolidated Electrodynamics Corp. The valve will seal a vacuum system from a diffusion pump without the contamination and inconvenience of a glass seal-off. It is also useful in handling very pure gases, such as in the study of breakdown characteristics of noble



gases. The valve consists of the valve assembly which becomes part of the vacuum system, and the driver mechanism which opens and closes the valve. Because they are separate, the valve can be baked out at high temperatures (up to 850° F.) without also baking the driver threads and lubricant.

For further information circle No. 1241 on literature request card, page 48-B.

Milling Cutter

Newcomer Products, Inc., has announced a new milling cutter for use in high speed milling with Throway carbide inserts. The new cutter has a

hardened alloy steel two-piece cutter body and patented locks to hold each Throway carbide insert in its indexed position. One RC milling cutter body can be used to mill steel or cast iron by using the proper grade of carbide.

For further information circle No. 1242 on literature request card, page 48-B.

Pre-Plating Bath

Northwest Chemical Co. has announced the development of a new improved zincate bath for the treatment of aluminum prior to plating. Features claimed for Alkalume include the ability to deposit a fine-grained, uniform coating in one pass; elimination of adhesion problems; low surface tension resulting in faster draining and reduced dragout; tolerance for chrome which assures con-

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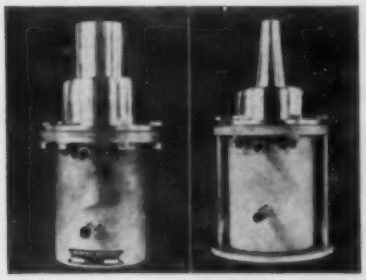
tinuous operation and longer life. Alkalume is amber colored which provides a visible check on the effectiveness of the rinsing.

For further information circle No. 1243 on literature request card, page 48-B.

Ultrasonic Transducers

Two new additions to the line of ultrasonic transducers has been announced by Acoustica Associates. The model at the left features water jacketed coupling slug. This arrangement permits use of high-power magnetostriction transducers for such



high temperature applications as molten metal degassing, grain refinement and alloy dispersing of metal castings. The model at the right features a tapered steel amplitude multiplier. This may be used for ultrasonic work when large peak-to-peak amplitudes are required, such as in drilling, blanking, shaping and grinding.

For further information circle No. 1244 on literature request card, page 48-B.

Oven

A new type of oven which permits loading and unloading down from the top has been announced by Grieve-Hendry Co. Work space dimensions

are 36 by 24 by 30 in. Ovens may be electrically heated or gas-fired, and can be furnished with either horizontal or vertical recirculating air flow pattern.

For further information circle No. 1245 on literature request card, page 48-B.

Potentiometer Wire

A new precious-metal alloy for potentiometer wire has been announced by Baker and Co. It is composed of palladium, gold and iron, and has a resistivity of 1100 ohms per cmf. and a temperature coefficient of -2.8×10^{-4} ohms per ohm per deg. C. between 0 and 100° C.

For further information circle No. 1246 on literature request card, page 48-B.

Insulation

Claud S. Gordon Co. has announced a new bonded staple yarn insulation that can be furnished on any standard or special thermocouple wire or thermocouple extension wire. It is suitable for use at temperatures up to 1600° F, is flexible and does not powder.

For further information circle No. 1247 on literature request card, page 48-B.

Core Blowing

A new automatic shell blowing machine, producing cores and molds, has been announced by C & S Products Co. By blowing resin-coated sand into electrically heated boxes, shell cores

or molds are made and ready for use in 30 sec. Hollow cores, solid cores, contoured shell molds or liner cores can be made. Shell cores up to 15 by 20 by 30 in. in height or shell molds up to 16 by 22 by 15 in. draw can be made on the machine.

For further information circle No. 1248 on literature request card, page 48-B.

Electrode Equipment

A new pitch-impregnated Unitrode nipple to improve electrode column joints has been announced by the Electrode Div., Great Lakes Carbon Corp. The nipple is partially impregnated with a zone of pitch. This zone completely covers the outside of the nipple and permeates down to a predetermined depth. Inside the zone, the nipple remains porous. As the electrode column is placed in operation, the pitch melts. At the same time, the air in the porous center of the nipple expands with the heat, forcing the liquid pitch throughout all the threads.

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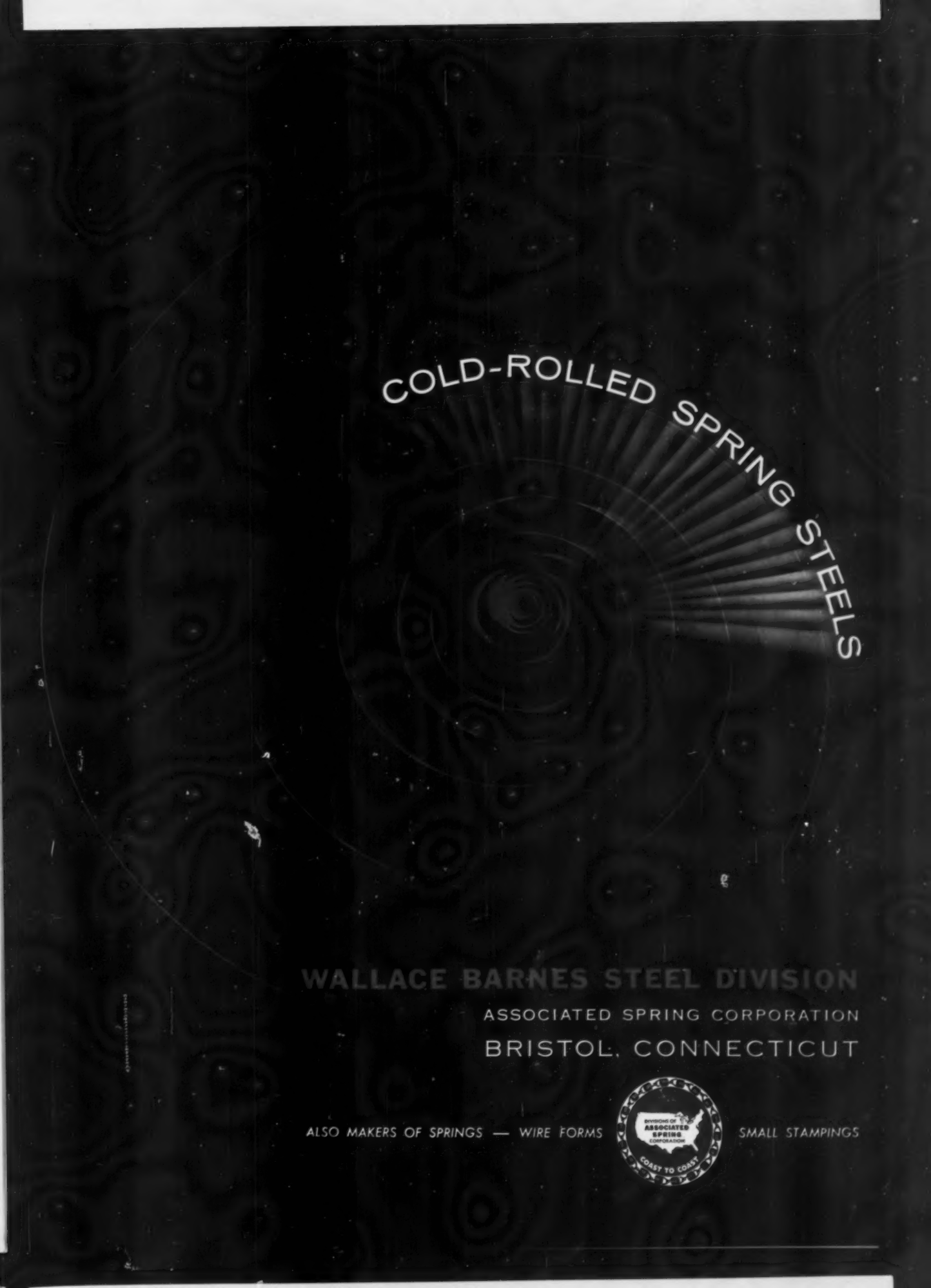
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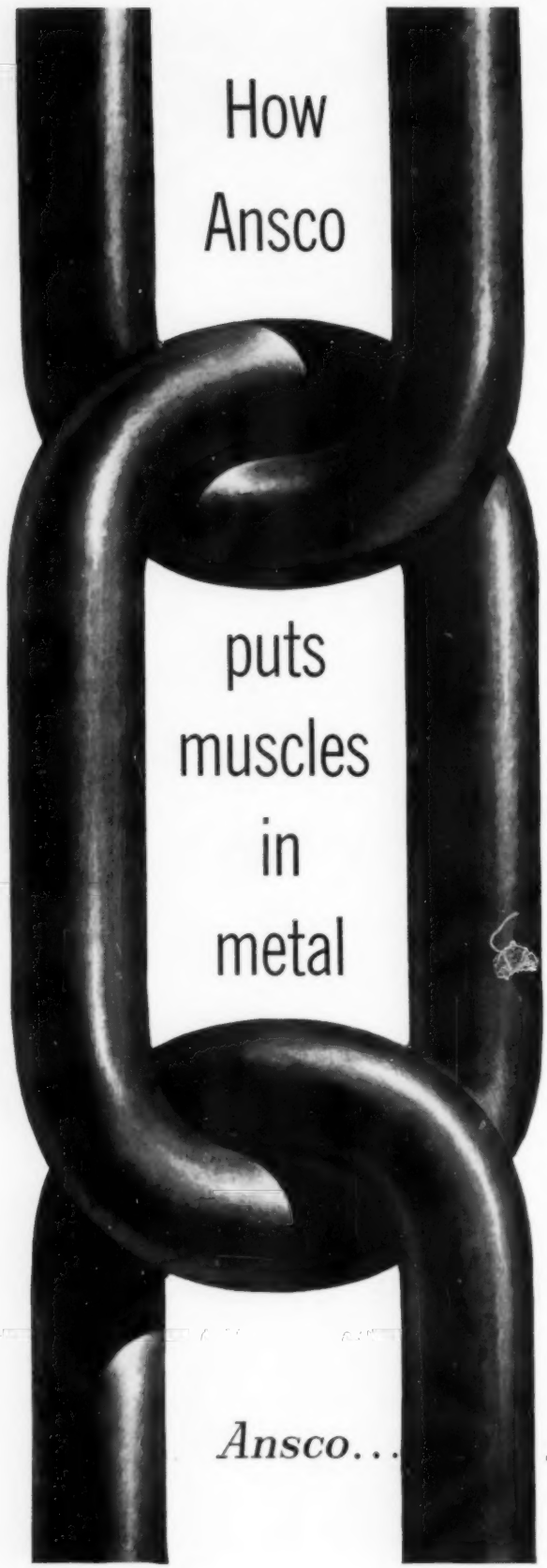

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As the electrode column continues to heat, the pitch cokes out, strengthening the threaded joint and making a better bond throughout.

For further information circle No. 1249 on literature request card, page 48-B

CO_2 Regulator

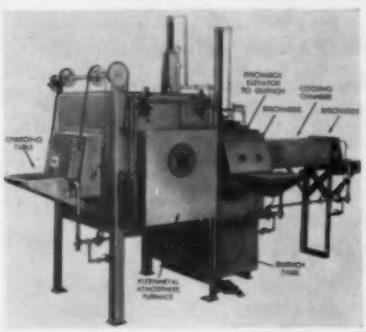
A heavy-duty carbon dioxide regulator has been announced by Linde Air Products Co. Effective operation is possible at any delivery pressure up to 200 psi. The new Oxweld R-69-400 regulator operates on a two-stage

principle of pressure reduction. Cylinder pressure is first reduced to a steady, intermediate stage and then to the desired delivery pressure. On both stages valves close with—not against—gas flows, minimizing pressure on working parts. A porous filter in the inlet connection blocks and absorbs any dirt or dust that might affect valve seating.

For further information circle No. 1250 on literature request card, page 48-B

Atmosphere Furnace

A new controlled atmosphere furnace, which has two methods of cooling the heated product in protective atmosphere, has been announced by the W. S. Rockwell Co. This furnace, which heats to 2400° F., is furnished with globar electric heating elements, but may be built for gas or oil heating. A quenching system is incorpo-



rated between the discharge end of the furnace and the cooling chamber. This consists of a steel oil-quench tank equipped with propeller type agitator and a rack elevator. For atmosphere cooling the work may be pushed through the tunnel-type, water-jacketed cooling chamber.

For further information circle No. 1251 on literature request card, page 48-B

Shears

A new series of air-operated shears for cutting ferrous and nonferrous strip has been announced by Curry Air Shear Corp. These shears are

available for cutting strip up to 3/16 in. thick in mild steel and widths from 24 to 84 in. The model illustrated is an up-cut type with 40 in. blades for cutting mild steel strip 38 in. by 12 gage or stainless strip 38 in. by 0.050 in.

For further information circle No. 1252 on literature request card, page 48-B

Potentiometer Servo-Mechanism

A new self-balancing electronic potentiometer servo-mechanism has been announced by the Bristol Co. It is furnished without a case, so that it may be built into the user's equipment. The mechanism consists of a group of standard Dynamaster instrument parts assembled on a circular base, and fitted with an indicating scale. When used with an amplifier, input transformer, and Syncroverter d-c. a-c. inverter, it forms a self-balancing dial indicator. The unit is available as a potentiometer or as an a-c. bridge. Dial indicator speeds of 1, 3 and 4½ sec. are offered, and one blind set alarm switch can be furnished.

For further information circle No. 1253 on literature request card, page 48-B

Burners

Planned-package burners to meet varying requirements for power generation, heat and steam generation have been announced by the W. N. Best Combustion Equipment Co. Top burner efficiency and automatic firing with any grade of fuel oil, and changeover in minutes to gas when it is more economical, are among the features of the Calorex burners.

For further information circle No. 1254 on literature request card, page 48-B

METALLURGICAL PROCESS ENGINEER

To Developand Improve Reactor Fuel Processes and Equipment

at HANFORD ATOMIC PRODUCTS OPERATION

Sharp advances in the new atomic power industry put a premium on men able to improve existing atomic fuel element manufacturing techniques and to guide new processes from laboratory through semi-works to the production line.

A man with this ability is needed now for an opening at the Hanford operation. His minimum qualifications are either a BS or MS degree in metallurgical engineering, plus 5-10 years in metallurgical process development work.

This position is in the new Fuels Preparation Department, a unit whose importance to the operation has opened unequaled opportunity for individual contribution; or for advancement into management.

If you meet these qualifications, you are invited to send your resume, in full confidence, to Mr. E. P. Galbraith, Manager, Technical Personnel Placement, Dept. FPD.

Hanford Atomic Products Operation

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Richland, Washington

Electric kiln and furnace users report

Biggest savings with Norton

"HOT RODS"

. . . the heating elements that outlast others up to 3 to 1!

SOME OF MANY TYPICAL "HOT RODS" REPORTS:

The American Lava Corporation says Hot Rods in two ceramic kilns averaged 6,883 and 6,880 hours — over 200% longer service than competitive heating elements.

J. Bishop & Company reports 18 months service from Hot Rods, compared to 6 months service from other elements. Result: 100% conversion to Hot Rods for electric furnaces used in specialized metal fabrication.

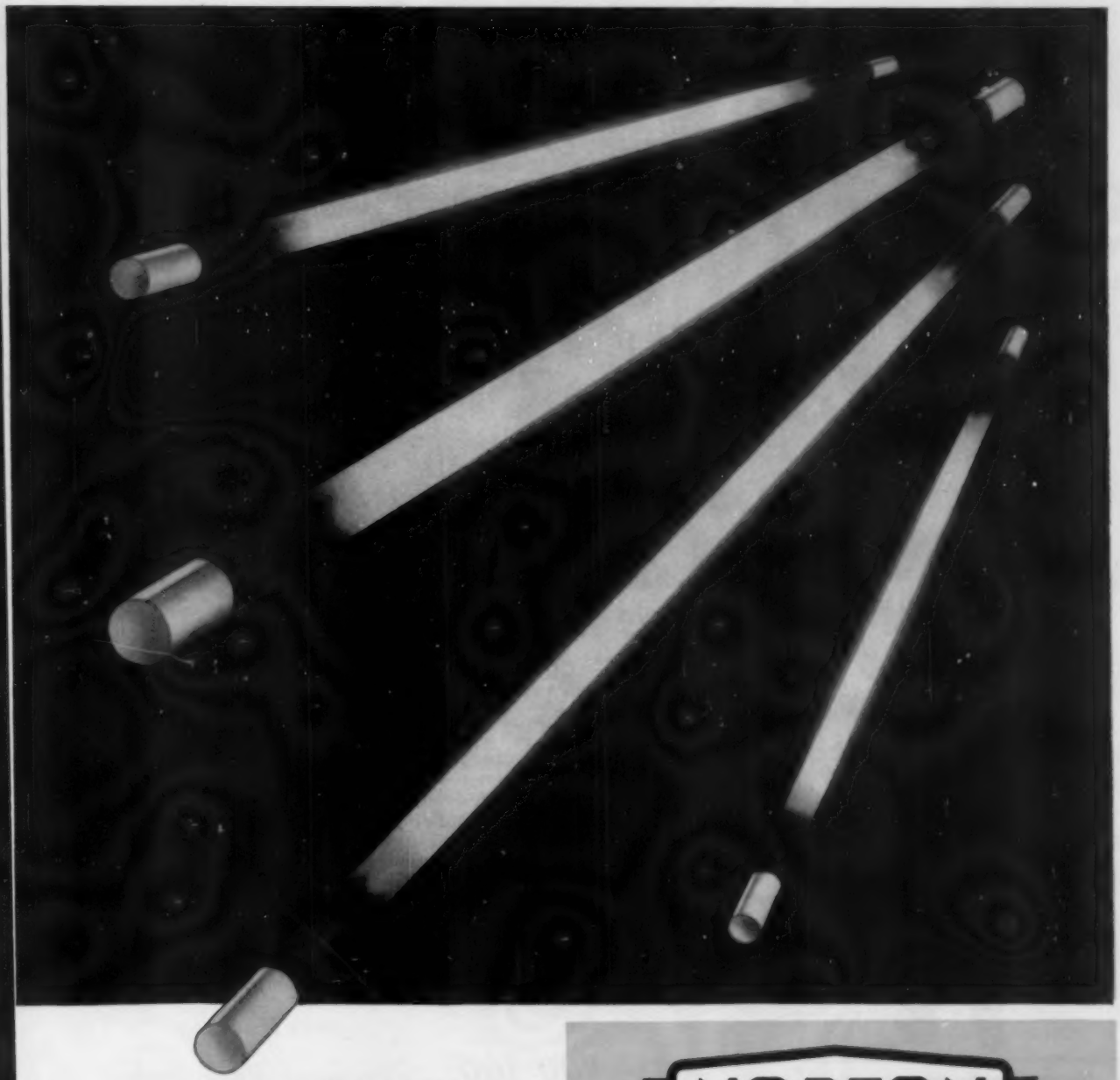
St. Lawrence Ceramics, Ltd., informs us that Hot Rods in their tunnel kilns are lasting much longer, providing steadier over-all heat, improving operating efficiency and cutting costs considerably.

G. W. Griffin Company tells how they are getting twice the life from Hot Rods in the gruelling intermittent service that is required in their Lindberg hydrizing furnaces.

H. K. Porter Co., Inc., announces a complete change-over to Hot Rods in their Alloy Metal Wire Division — because of the better than 3 to 1 service life provided by these outstanding elements in a battery of electric furnaces.

Evans Case Company now specifies Hot Rods for Pereny periodic electric kilns — because their longer life means over-all economy.

General Riveters, Inc., writes: "Hot Rods provide top performance and maintenance-free service. We like this designed-in service."



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For further facts on these reports, send for user folder and catalog on *Norton Heating Elements.* NORTON COMPANY, Refractories Division, 324 New Bond Street, Worcester 6, Mass.

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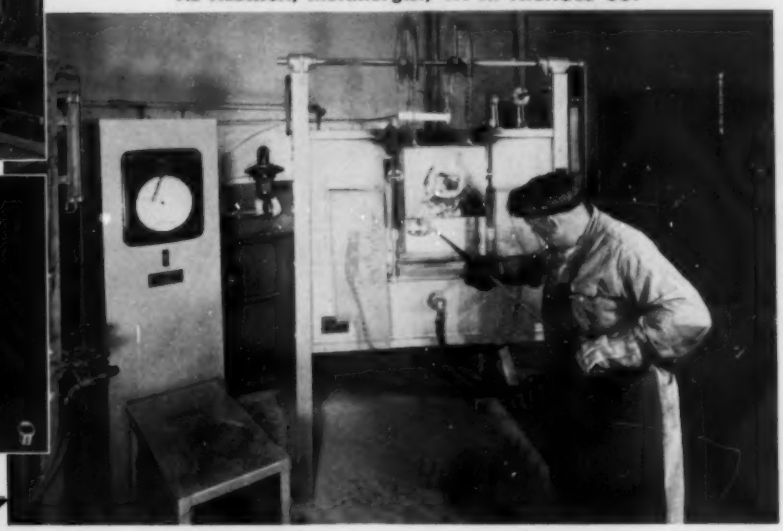
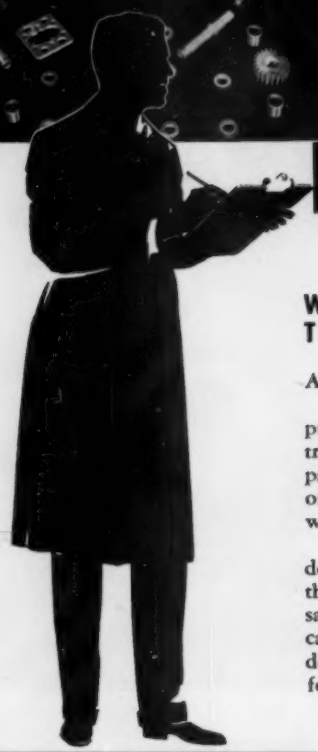
"Precision Control is Vital in Our Heat Treating of High Speed Steel..."

AL ALDRICH, Metallurgist, W. H. NICHOLS CO.





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AL ALDRICH *testifies:*

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- ☐ Carbo-Nitriding
- ☐ Tempering
- ☐ Vacuum Heat Treating
- ☐ Bright Heat Treating
- ☐ Stainless Steel Heat Treating
- ☐ Sintering
- ☐ Copper Brazing and Soldering
- ☐ Lead Pot Hardening and Tempering
- ☐ Atmosphere Equipment
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APPLICATION and EQUIPMENT new literature

1256. Abrasion Tester
Bulletin 5409 on new model standard abrasion testing set describes machine and its operation. *Tabor Instrument Corp.*

1257. Abrasive
New bulletin on aluminum oxide abrasive grain. Advantages. Toolroom grinding wheels using this abrasive. *Simonds Abrasive Co.*

1258. Alloy Steel
40-page book on applications of heat treated, special alloy steel. *Jones & Laughlin*

1259. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

1260. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U. S. Steel*

1261. Aluminum
16-page bulletin lists sizes, weights, lengths of aluminum in rod, bar, plate, sheet. Guide to selection, finishes, mechanical properties. *Ryerson*

1262. Aluminum
4-page folder on colored aluminum coil. Advantages, characteristics of finishes. *Reynolds Metals Co.*

1263. Aluminum Alloy
Bulletin 103 on high strength aluminum alloy which ages at room temperature. *Federated Metals Div.*

1264. Aluminum Bronze
8-page booklet on aluminum bronze bearing material which is forgeable, corrosion resistant, lightweight. *Mueller Brass*

1265. Aluminum Castings
Compilation of data on the Antioch process for making aluminum castings. Variety of castings described and method of casting by this process. *Morris Bean*

1266. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1267. Aluminum Extrusions
28-page book on extruded aluminum products. Design, tolerances, applications. *Revere*

1268. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions, Inc.*

1269. Aluminum Melting
Folder on electric furnaces for the aluminum alloy foundry. *Ajax Engineering*

1270. Aluminum Strip
20-page booklet on how it is made, sizes and weights of coils. Technical data on aluminum alloys used. *Scovill*

1271. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

1272. Atmosphere Furnace
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

1273. Atmosphere Furnaces
New 4-page bulletin on single and double recuperative atmosphere furnace for forging and rolling. *Furnace Div., Lithium Co.*

1274. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

1275. Blast Cleaning
Complete information on Malleabrasive for cleaning and finishing. *Globe Steel Abrasive*

1276. Blast Cleaning
Bulletin No. 703 gives complete specifications and dimension of Blastmaster barrels from 1.5 cu. ft. to 27 cu. ft. Automatic operations. *Pangborn Corp.*

1277. Boron Additive
6-page article on use of grainal as boron-additive alloy and properties of grainal steels. *Vanadium Corp.*

1278. Brazing
New 4-page catalog on high-temperature brazing alloys. Characteristics and physical properties. *Wall Colmonoy Corp.*

1279. Brazing
16-page pocket-sized guide to selective fluxing for low temperature silver brazing. *American Platinum*

1280. Brazing
52-page publication GEA 3193C on how and where to use electric furnace brazing. Limiting creep of brazing metal, selecting the brazing metal, strength of furnace-brazed parts, how to braze cast iron, causes of distortion and other topics considered. *General Electric Co.*

1281. Buffing and Polishing
24-page catalog on cutting, coloring and double duty compounds for 12 metals, plastics and rubber. *Hanson-Van Winkle-Munning*

1282. Burner
Bulletin 111 on vortex burner gives description and output data. *Thermal Research & Engineering*

1283. Calibrating Machine
Bulletin 115 on calibrating system for accurate measurement of mechanical forces. *Morehouse Machine*

1284. Carbide Cutters
Bulletin on milling cutters using throw-away carbide inserts. Prices and specifications. *Newcomer Products, Inc.*

1285. Carbides
15 data sheets on Carmet carbide grades. Typical applications, analysis, physical characteristics and grain structure. *Allegheny Ludlum Steel Corp.*

1286. Carbon Control
Bulletin C-22 and reprint on Carbotronik for automatic control of carbon potential of atmospheres. *Ipsen*

1287. Carbon Control
Bulletin SC-168 on system for automatically controlling carbon potential in continuous and batch furnaces. *Surface Combustion Corp.*

1288. Casehardening
32-page booklet on casehardening of steel by nitriding. *Armour Ammonia Div.*

1289. Cast Iron
Chart of specifications for gray cast irons and nodular cast irons. *Gray Iron Founders' Society*

1290. Castings
Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

1255. Magnesium and Titanium

Design data for magnesium and titanium are presented in this new 44-page booklet. Physical and mechanical properties, mechanical properties at elevated temperatures, metal

weights, forming characteristics, specification tables, corrosion behavior, surface treatments, welding and joining, machining, heat treatment and stress relief, and other similar design data are covered. *Brooks & Perkins*

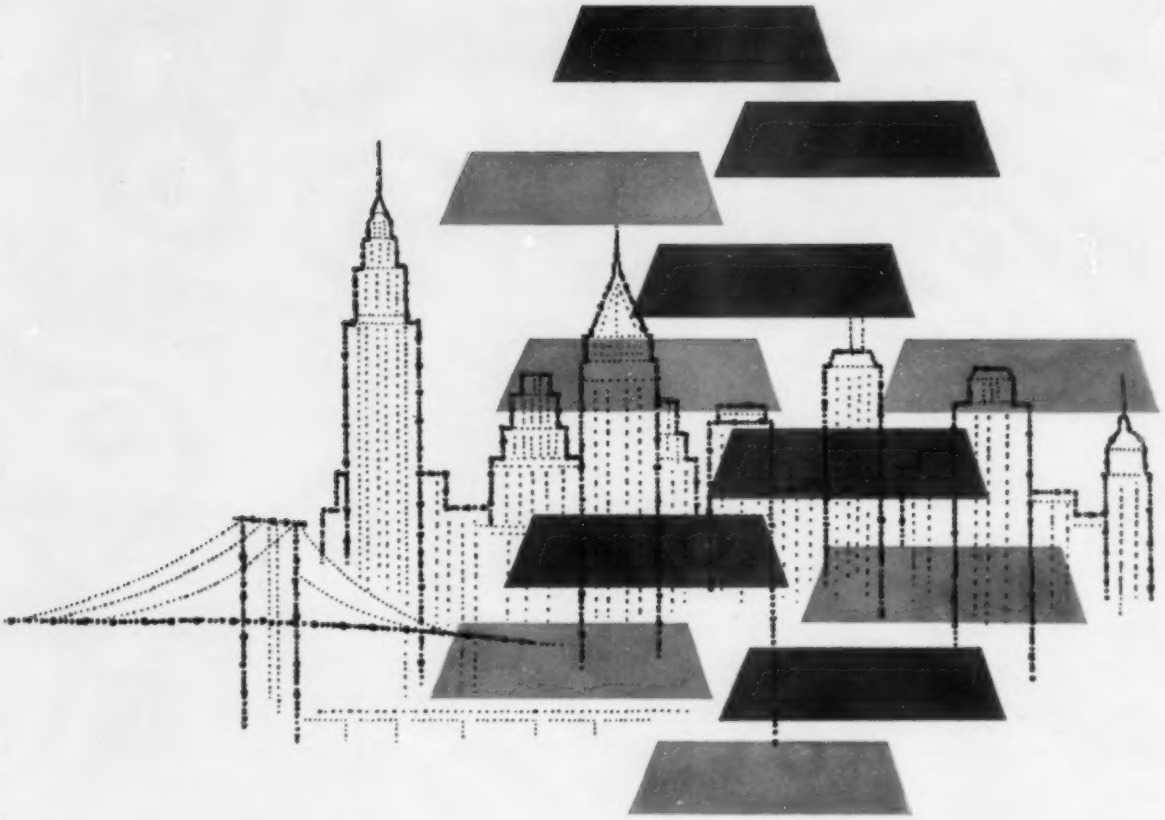
1291. Castings
Literature on shell or sand castings of ArmaSteel, malleable iron or gray iron. *Central Foundry Div.*

1292. Centrifugal Castings
Folder on which centrifugal castings are available. Compositions, properties, standard designations. *Sandusky Foundry and Machine Co.*

1293. Centrifugal Castings
Folder on advantages of centrifugally cast thermalloy. *Electro-Alloys Div.*

1294. Chemicals
22-page bulletin on industrial chemicals lists those available and illustrates their manufacture and testing. *Harshaw*

1295. Chromate Finishing
File on chromatic conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*



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1296. Chromium Stainless
12-page book on fabrication and use of Type 430 stainless steel. *Sharon Steel*

1297. Chromium Treatment
Reprint describes how chromium impregnating of steel affects properties, how it is done, applications. *Chromalloy*

1298. Clad Metals
New technical bulletin CM-901 discusses types of clad metals, applications, materials and cost savings with clad metals. *American Silver Co.*

1299. Cleaners
Folder on immersion, electrolytic, spray cleaners, phosphate coaters, strippers, drawing compounds, additive agents. *Northwest Chemical*

1300. Cleaning
Data sheets on acid activators to promote removal of scale and oxides from steel and iron. *Swift Ind. Chem.*

1301. Cleaning
44-page booklet, "Some Good Things to Know About Metal Cleaning", discusses tank, barrel and machine cleaning, pickling, zinc phosphate coating, rust prevention and other processes. *Oakite*

1302. Coated Metals
New bulletin on roll coating shows how it is done and includes samples. *Roll Coater, Inc.*

1303. Coated Pipe
4-page folder on new plastic-coated steel pipe and tubing. How it solves the problem of pipeline corrosion. *Republic Steel*

1304. Coatings
New bulletin gives uses of various conversion coatings for zinc and cadmium. *Chemical Corp.*

1305. Coatings
New 4-page catalog on heat-proof protective coatings. Basic types, applications, methods of applying and temperature ranges. *Markal Co.*

1306. Cobalt Alloy
12-page booklet, "Haynes Alloy No. 25", tells of the unique properties of this cobalt-base alloy. *Haynes Stellite*

1307. Cold Forming
4-page folder on die-form process for cold reduction of steel bars into multi-diameter shaft blanks for finish turning or grinding. *Republic Steel*

1308. Cold Rolled Steels
32-page booklet on stainless, alloy and carbon spring steels, and other specialties. Melting, temper, finishes. *Crucible Steel*

1309. Compressors
12-page bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

1310. Controlled Atmospheres
Illustrated literature describes controlled atmosphere installations. *Gas Atmospheres, Inc.*

1311. Controls
56-page catalog 857 on automatic controls for heating and industrial applications—pressure, temperature, liquid level, etc. *Mercoid Corp.*

1312. Conversion Table
Wall chart converts inches to centimeters, watts to horsepower, etc. *Precision Equipment Co.*

1313. Conveyors
Bulletin MF-200 on conveyor standardization describes prefabricated sections for making customized conveyors. *May-Fran Engineering*

1314. Copper Alloys
60-page catalog on phosphor bronzes, nickel silvers, beryllium copper, cupronickel. Chemical and physical data. Engineering tables. *Riverside Metal*

1315. Copper Alloys
64-page publication C-25 on electrical properties and uses of copper and copper alloys. *American Brass Co.*

1316. Copper Alloys
40-page technical data book on eleven copper alloys. Properties, cleaning, annealing. *Seymour*

1317. Core Binders
Bulletin 450, line of binders for oil-sand cores, air-setting cores, CO_2 gassed cores and resin bonded cores. *Foundry Div., Archer-Daniels-Midland Co.*

1318. Cupola Linings
4-page folder on cupola blocks illustrates and describes three shapes. Charts of number of pieces required for various diameters of cupolas. *Harbison-Walker Refractories*

1319. Cut-Off Machine
Folder on abrasive-wheel cutting-off machine. Components, typical cuts. *American Instrument Co.*

1320. Cutting Machine
New 8-page catalog gives cutting range, weights, dimensions and other specifications for No. 4 Monograph portable shape cutting machine. *Air Reduction Sales Co.*

1321. Cutting Oil
Bulletin 39 on transparent cutting oil which is designed for use on a wide variety of steels. *Sun Oil Co.*

1322. Cutting Tools
New 12-page catalog D-56 on aluminum oxide cutting metals, tool tips, throw-away inserts, cylinders and other machine turning and cutting tools. *Metal Carbides*

1323. Cutting Torch
New 4-page folder on process and torch for cutting, gouging, beveling and grooving all metals. *Arcair Co.*

1324. Deep Drawing
4-page bulletin 138 on lubricants for deep drawing. Each lubricant is described, evaluated and its specific applications noted. *Magnus Chemical*

1325. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

1326. Degreasing
34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

1327. Degreasing
40-page book on trichlorethylene gives specifications, properties, uses, handling and storage, toxicity and safety measures. *Hooker Electrochemical Co.*

1328. Descaling
10-page bulletin 203, furnaces used for sodium hydride descaling. *A. F. Holden*

1329. Descaling Equipment
36-page booklet on hydraulic descaling equipment. Operating principles. Specifications. *Commercial Shearing and Stamping Co.*

1330. Die Steel
Folder and stock list on Olympic FM air hardening, high carbon-high chromium die steel with sulphide additives for improved machinability. *Latrobe Steel Co.*

1331. Dilatometer
16-page bulletin on Chevenard dilatometers for laboratory use. Principles of operation, components. *R. Y. Ferner Co.*

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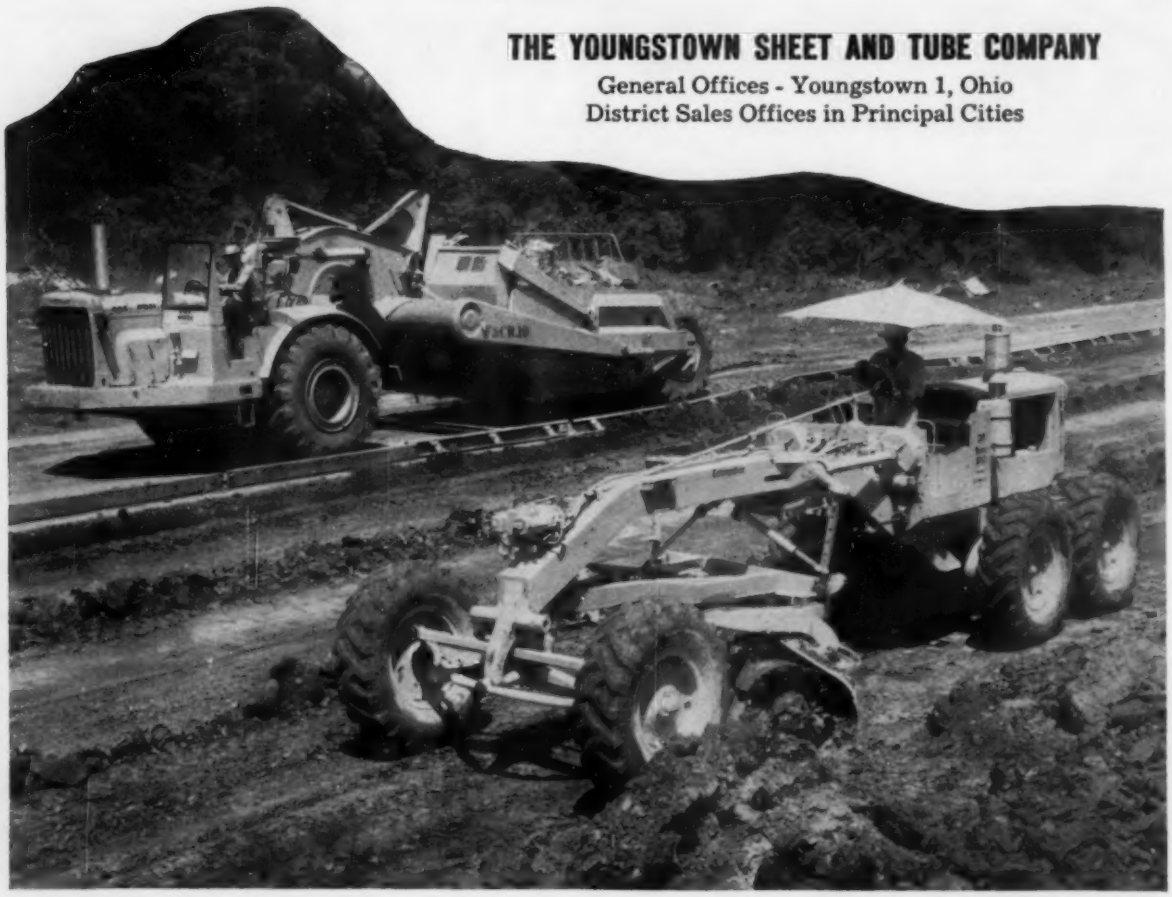

1332. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

1333. Electric Furnaces
12-page bulletin on box-type electric furnaces for toolroom applications. Performance data for each type. *Westinghouse Electric Corp.*

1334. Electric Furnaces
Bulletin 441 on box-type electric furnaces diagrams and describes the furnaces and lists specifications. *Hevi Duty Electric*

1335. Electric Furnaces
Catalog of electric furnaces and ovens for hardening, tempering, annealing, drawing, drying, baking, enameling. *Cooley Electric Mfg.*

1336. Electric Ovens
8-page bulletin describes mechanical convection ovens with fully automatic proportional wattage control. *Blue M Electric*

1337. Electrocoated Wire
8-page bulletin on new wire materials—Nickelply and Brassply, electrocoated steel wire. How it may be formed, bent and twisted without breaking the coating. *National Standard*

1338. Extrusions
Bulletin on extruded seamless alloy and stainless steel tubing. Properties, shapes. *Metals Processing Div., Curtiss-Wright Corp.*

1339. Ferro-Alloys
32-page book tells how ferro-alloys are made and how they are used. *Electro Metallurgical Co.*

1340. Filters
8-page bulletin on tubular screen, pressure and settling filters, magnetic separators. *Industrial Filtration Co.*

1341. Finishing Machines
12-page catalog on basic types of automatic transverse spray finishing machines. Basic design, advantages. *DeVilbiss Co.*

1342. Flaw Location
New 4-page folder on dye penetrant method of flaw location. Pre-cleaning, applying penetrant, removing excess penetrant, applying developer and interpreting results are discussed. *Turco*

1343. Flow Meters
Bulletin 203 on flow meter for gas used in heat treating. *Waukee Eng'g*

1344. Fluoroscopy
12-page booklet on fluoroscopy for nondestructive internal inspection. Explains image amplifier. *Westinghouse Electric X-Ray Dept.*

1345. Forgings
Bulletin on forge steelmaking, open die forging, machining, heat treating and finishing. *National Forge*

1346. Forgings
New 16-page booklet on application of steel forgings—drop, press and upset. *AmForge Div., American Brake Shoe Co.*

1347. Forgings
12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div., Baldwin-Lima-Hamilton*

1348. Forgings
Series of articles on modern forging methods. *Hill Acme*

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Data on forging products and electrically welded composite die sections. *Composite Forgings, Inc.*

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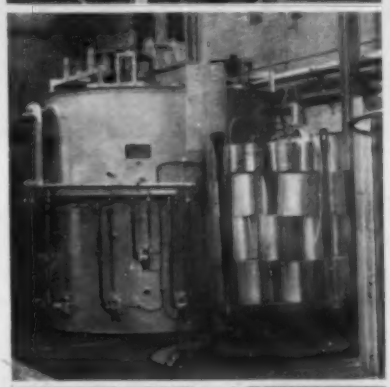

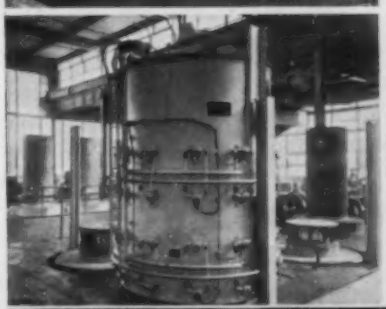

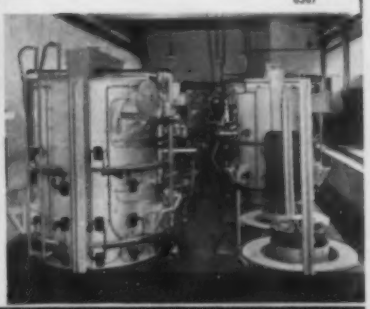

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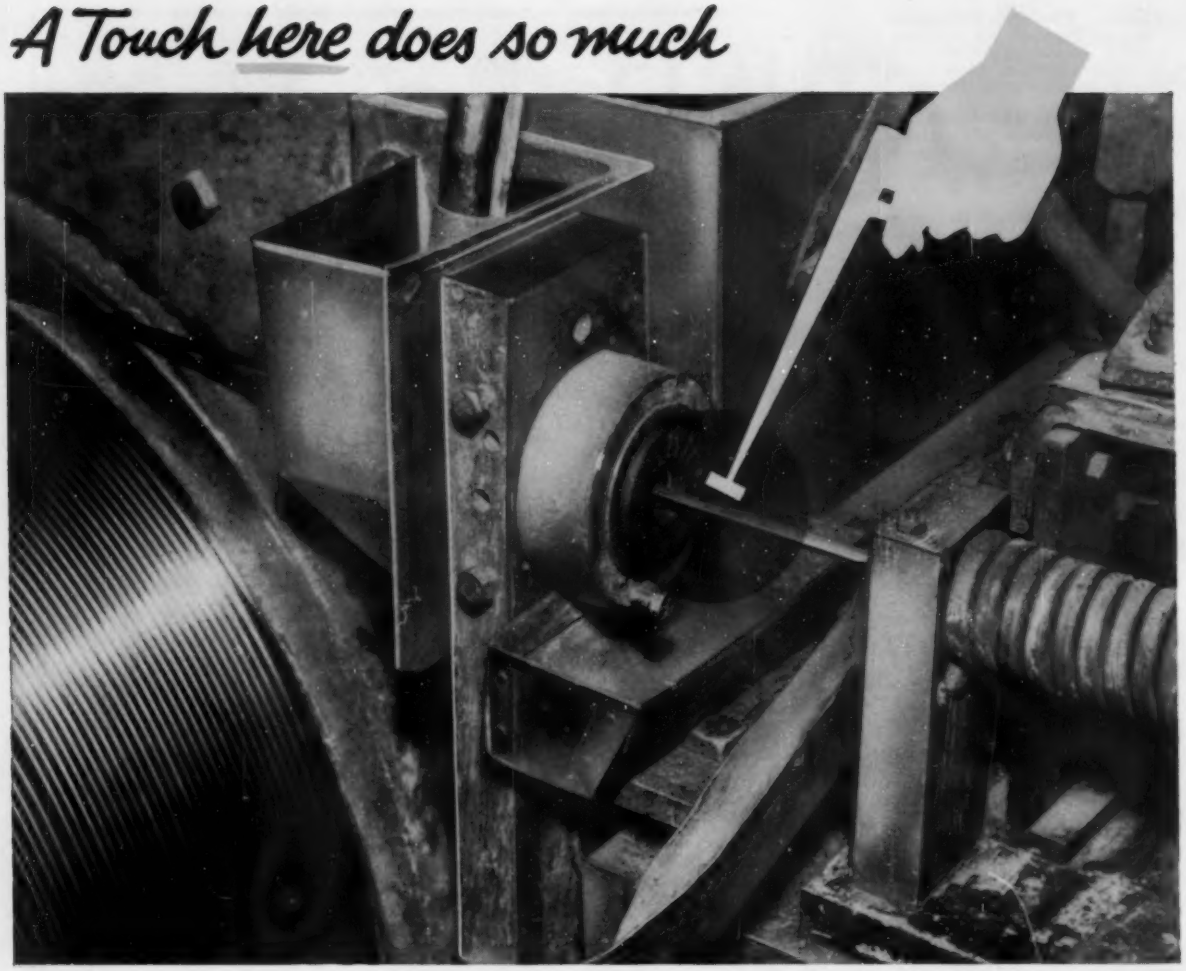

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94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

1351. Formed Shapes
26-page catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

1352. Forming
Brochure on high-speed automatic machine. Rapid production features. *Cyril Bath Co.*

1353. Freezers
New 4-page folder on six different models. Standard and optional features, temperature ranges, capacities, inside and outside dimensions. *Webber Corp.*

1354. Furnace Fixtures
Bulletin 111 on cast Ni-Cr fixtures for gas carburizing. *Fahralloy*

1355. Furnaces
Bulletin 424R on gas, oil, and electric revolving retort furnaces for annealing, hardening, drawing. *W. S. Rockwell Co.*

1356. Furnaces
4-page bulletin on field-erected production furnaces of various types for heat treating, continuous enameling, aluminum melting. *Lindberg Industrial Corp.*

1357. Furnaces
New catalog on standard and special furnaces and ovens to 3000° F. *L & L Mfg.*

1358. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

1359. Furnaces
Folder describes complete set up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

1360. Furnaces
16-page bulletin 135 on industrial furnaces and atmosphere generators. Continuous systems. *Continental Industrial Engineers*

1361. Furnaces
Data on line of melting, heating and heat treating furnaces for ferrous and nonferrous metals. *Loftus Engineering*

1362. Furnaces
High-temperature furnaces for temperatures up to 2000° F. are described in bulletin. *Carl-Mayer Corp.*

1363. Furnaces
Monthly bulletin on used equipment. *Metal Treating Equipment Exchange*

1364. Furnaces, Heat Treating
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

1365. Gas Analysis
Bulletin 482 on gas chromatograph for analysis of gases and low-boiling liquids. How it works. *Harshaw Scientific*

1366. Gold Plating
Folder on salts for bright gold plating. Equipment needed. *Sel-Rex*

1367. Grinding Machine
Folder on grinding machine with continuous inspection. Specifications. *Cleveland Grinding Machine Co.*

1368. Hardness Tester
4-page bulletin on air-operated Brinell metal hardness tester. Operating principles, specifications. *Tinius Olsen Testing Machine Co.*

1369. Hardness Tester
Bulletin on hardness tester for all regular and superficial Rockwell tests. *Kent Cliff Div., Torsion Balance Co.*

1370. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

1371. Hardness Tester
Bulletin on how to test large gears with portable Brinell tester. *King Tester*

1372. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1373. Hardness Tester
Bulletin on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

1374. Hardness Testers
Folder on portable hardness testers for testing of various sizes, shapes and types of metal. *Newage International*

1375. Hardness Testers
20-page bulletin on models, applications and how to use superficial hardness testers. *Wilson Mechanical Instrument*

1376. Hardness Testing
8-page catalog B-953 on principles and standards of Brinell hardness testing, and types of machines. *Steel City Testing Machines*

1377. Hardness Tests
New bulletin covers methods and motorized reflex Brinell machines for production testing. *Gries Industries*

1378. Heat Resistant Alloy
10-page article on how to get best service out of standard grades of heat resisting alloys by proper selection. *Rolled Alloys*

1379. Heat Treating
8-page article on heat treatments for ductile iron. Process for developing tensile strength from 60,000 to 150,000 psi. and elongation to 25%. *International Nickel*

1380. Heat Treating
Bulletin describes baskets, crates, trays, furnace parts for heat treating. *Stanwood*

1381. Heat Treating
New 12-page bulletin on design advantages, sizes of tool steel atmosphere furnaces. Endothermic atmosphere generators. *C. I. Hayes, Inc.*

1382. Heat Treating
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

1383. Heat Treating
Continuous furnace for heat treating rivets at Simmons Co. described in Metal Minutes, Dec.-Jan. 1957. *Sunbeam*

1384. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div.*

1385. Heat Treating Belts
Catalog of conveyor belts and data for their design, application and selection. *Ashworth Bros.*

1386. Heat Treating Belts
New 16-page booklet on selection of steel processing conveyor belts gives complete specifications. *Colorado Fuel & Iron*

1387. Heat Treating Fixtures
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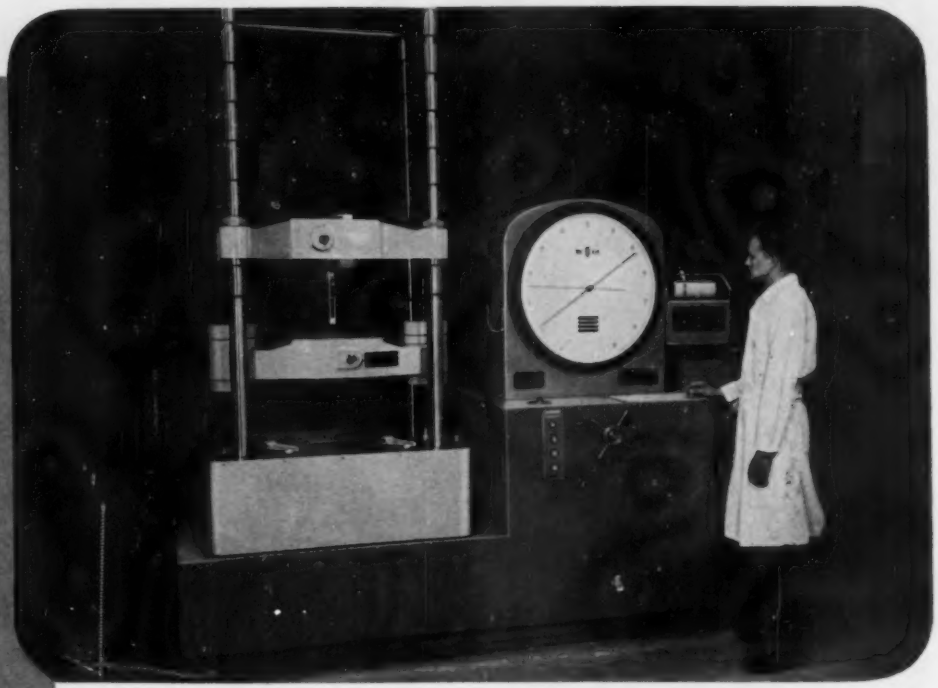

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12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

1389. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1390. Heat Treating Fixtures
Folder on carburizing boxes, trays, heat treat fixtures and baskets. *Misco.*

1391. Heat Treating Furnaces
12-page booklet on various heat treating furnaces contains chronology of advances. *Holcroft*

1392. Heaters
Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

1393. Heating Elements
24-page booklet on elements for electric furnaces and kilns includes technical data, uses, physical and electrical specifications. *Norton*

1394. Heating Elements
12-page bulletin gives typical applications of silicon carbide heating elements. Hints on handling, unpacking, storage, installation, replacement. *Globar Div., Carborundum*

1395. Heating Time Calculator
Slide chart gives heating time in salt baths for steel sections of different diameters. *Ajax Electric*

1396. High-Strength Steel
New 24-page bulletin on steel bars made by elevated temperature drawing. Strength without heat treatment, machining data, fatigue resistance, wearability. *LaSalle Steel*

1397. High-Temperature Alloy
14-page bulletin on Udimet 500 gives composition, heat treatment, machinability, hot working characteristics and properties. *Utica Drop Forge and Tool*

1398. High-Temperature Steels
87-page book on factors affecting high-temperature properties. 45 pages of data on tensile, creep and rupture properties of 21 high-temperature steels. *U. S. Steel*

1399. High-Tensile Steel
Bulletin on nickel-copper steel of low-alloy, high-strength type. *Youngstown Sheet and Tube*

1400. Humidity Instruments
New 22-page bulletin on indicating, recording and controlling wet and dry bulb instruments and psychrometers. *Bristol Co.*

1401. Induction Heating
20-page booklet, "Dr. Northrup's Fireless-Wireless Furnace", gives story of development of high-frequency induction heating. *Ajax Electrothermic Corp.*

1402. Induction Heating
8-page bulletin on high-frequency motor-generator sets for induction heating. *Ohio Crankshaft*

1403. Induction Heating
Bulletin on heat treating, joining and hot forming. Charts on current penetration and equipment for heating steel above curie point. *Magnethermic Corp.*

1404. Induction Heating
Folder 15C8053A gives advantages of induction heating and specifications and dimensions of induction heater. *Allis-Chalmers.*

1405. Induction Heating
New bulletin on remote heating station for motor generator induction heating equipment. *Lindberg Engineering Co.*

1406. Induction Melting
Bulletin 70 on furnace. Controls, designs. *Inductotherm Corp.*

1407. Industrial Heating
Booklet on process heating operations for light metals. *Michigan Oven Co.*

1408. Infrared Analyzer
4-page data sheet on infrared gas analyzer describes instrument, its operation and maintenance. *Leeds & Northrup*

1409. Inspection
Descriptive information and instructions for new inspection process to detect surface flaws on all ferrous and nonferrous metals. *Zaco Laboratories*

1410. Instruments
4-page folder on new micro-microammeters. Models, circuits, specifications. *Keithley Instruments*

1411. Insulating Firebrick
8-page bulletin R-43 gives description of relationship between heat losses and weight of refractory linings. *Refractories Div., Babcock & Wilcox*

1412. Insulators
Bulletin P1-55 on insulators and insulating tubing. *McDanel Refractory Porcelain*

1413. Investment Casting
New bulletin on gas fired furnaces for investment casting. Also includes chart of characteristics of typical investment casting alloys. *Surface Combustion*

1414. Laboratory Equipment
Bulletin No. 832 on connecting and valving devices for gas, vapor and liquid flow systems of analytical instruments. *Burrell Corp.*

1415. Laboratory Furnaces
Data on nonmetallic resistor furnaces for research, testing or small-scale production. *Harrop Electric Furnace*

1416. Low-Temperature Brazing
Folder on brazing copper to nichrome, stellite to steel, brass to brass, steel to cast iron. *Handy & Harman*

1417. Lubricant
Fact sheet on high-temperature lubricant for parts operating in oven temperatures to 400° F. *Tower Oil Co.*

1418. Lubricant
Bulletin 103A on fringe area lubrication with molybdenum disulfide lubricants for extreme bearing pressures and all temperatures. *Alpha Molykote*

1419. Lubricants
New edition of 4-page bulletin lists 44 colloidal and semi-colloidal dispersions of graphite, molybdenum disulfide, zinc oxide and others. *Acheson Colloids Co.*

1420. Lubricants
8-page booklet on colloidal greases, forging compounds, hydraulic concentrate and others. *Grafo Colloids*

1421. Lubrication
16-page bulletin 155 on hydraulic oil data and lubrication guide as related to hydraulic presses. Supervision of hydraulic systems, preventive maintenance, oil specifications. *Lake Erie Machinery Corp.*

1422. Machining Copper
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32-page booklet gives cutting speeds, feeds, rakes, clearances for more than 40 copper alloys. *American Brass.*

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42-page booklet on wrought forms of

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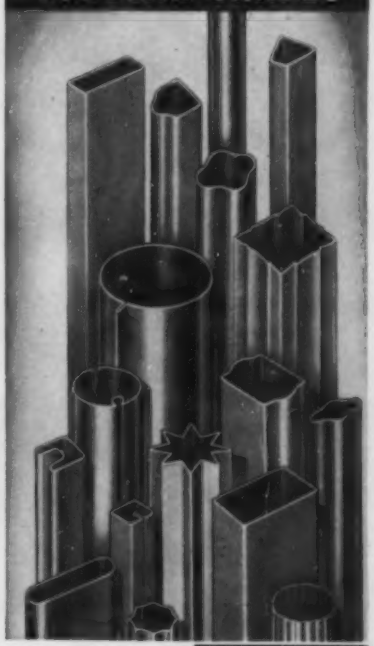

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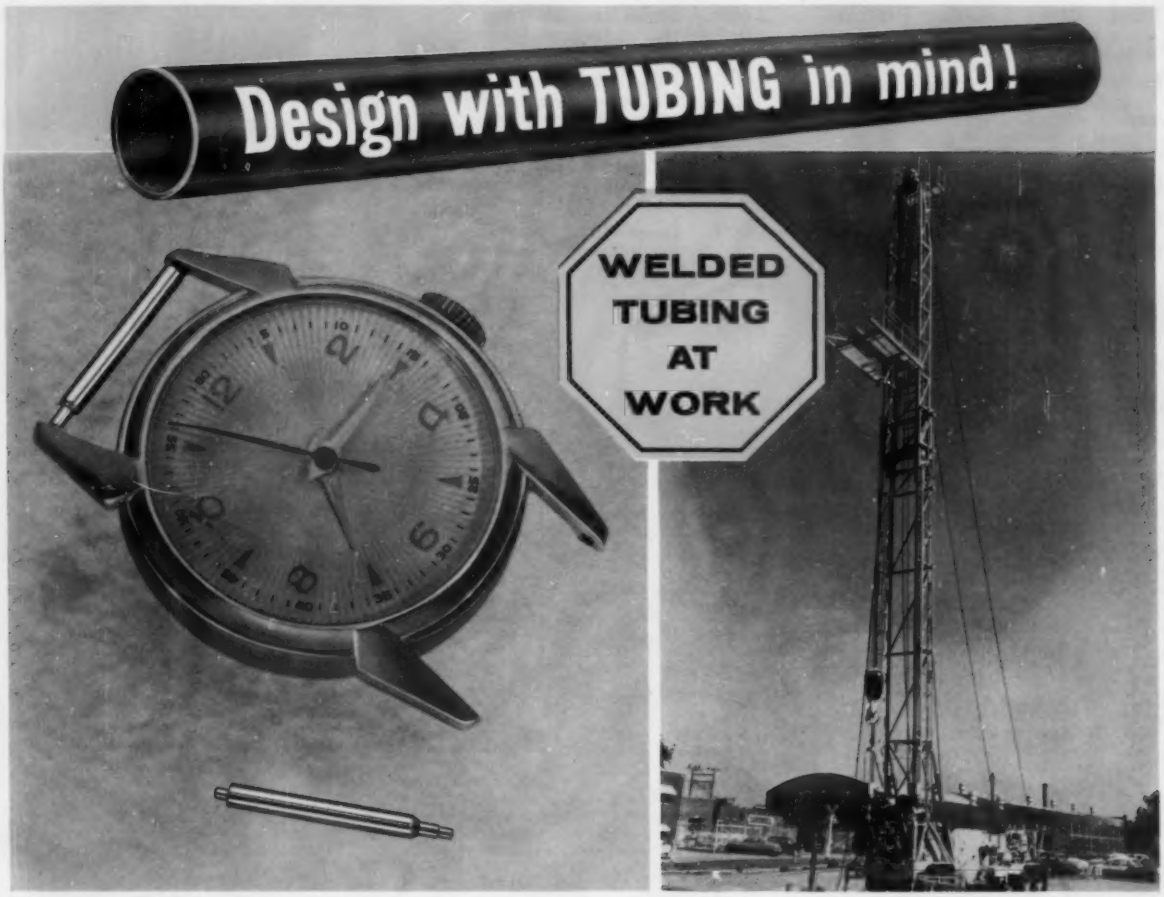

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10-page reprint on an investigation of zirconium chloride, zirconium fluoride, 40% zirconium-magnesium material for making magnesium zirconium alloys. *Titanium Alloy Mfg. Div.*

1426. Manganese

9-page article on electromanganese. Manufacturing procedures, product characteristics, uses. In Foote Prints, V. 28, No. 2. *Foote Mineral Co.*

1427. Marking Machines

Data on various types of marking machines from bench mounted machines for light duty marking to machines capable of marking at up to 6 tons table pressure. *Jas. H. Matthews & Co.*

1428. Master Alloys

24-page pocket bulletin on high alloy materials also includes metric equivalents tables, element melting points, temperature conversion tables. *Alloy Metal Products, Inc.*

1429. Mechanical Cleaning

Booklet on how brushes are used for cleaning welds, stainless sheets, hot cast iron, automotive parts, brass fixtures. *Brush Div., Pittsburgh Plate Glass*

1430. Melting Guide

Selector guide for heating equipment and control for solder, tin and lead melting. *General Electric Co.*

1431. Metal Cleaning Equipment

Folder gives data on metal cleaners for use with water in still-tank or spray-washing equipment. *Solventol*

1432. Metal Cutting

64-page catalog No. 30 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric*

1433. Metallograph

12-page book on desk-type metallograph. *American Optical*

1434. Metallographic Equipment

12-page catalog E-29 describes bright-field equipment for visual observation and photography. *Bausch & Lomb*

1435. Metalworking

50-page bulletin 38 on computations for metalworking in presses. Diagrams for computing pressure, formulas and charts on blanking and shearing, drawing and reducing, ironing, coining, sizing, forging, extrusion. *E. W. Bliss Co.*

1436. Microhardness Tester

6-page bulletin 125-56 on nondestructive microhardness testing instrument and metallurgical microscope. How it works, features and advantages, applications. *Sheffield Corp.*

1437. Microhardness Tester

Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

1438. Microscopes

40-page catalog on metallographs, metallurgical, toolmakers, stereoscopic, polarizing, phase and other microscopes. *Unitron Instrument Div., United Scientific*

1439. Moisture Measurement

12-page bulletin on how to measure water vapor in air and other gases. Gravometric, dew point and wet and dry bulb methods, and others. *Pittsburgh Lectrodryer*

1440. Nondestructive Testing

8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

1441. Nonflammable Rust Preventive

Bulletin on rust preventive compound which is water soluble, nontoxic and nonflammable. *Production Specialties*

1442. Oil Quenching

Catalog V-1146 on self-contained oil cooling equipment. Selection tables for volume of oil required and oil recirculation rates. *Bell & Gossett*

1443. Oil Quenching

8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1444. Ovens

Catalog on oven furnaces gives operating advantages, construction, operating temperatures. *American Gas Furnace Co.*

1445. Oxygen Analyzer

Data sheet on continuous-flow type oxygen analyzer. Description, applications, principles of operation. *Consolidated Electrodynamics Corp.*

1446. Perforated Metals

New 4-page folder gives ordering specifications and patterns. *Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp.*

1447. Phosphating

Folder includes general discussion of phosphating, how it works and use of coatings as bonds for paint or other organic finishes. Phosphating reference chart. *Turco Products*

1448. Phosphor Bronze

Facilities for rolling, cleaning, welding, trimming and treating phosphor bronze. *Rolling Mill Div., Miller Co.*

1449. Photomicrography

Catalog E-210 on sliding base, high or low power photomicrographic equipment. *Bausch & Lomb*

1450. Pickling Baskets

12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

1451. Pickling Baskets

Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1452. Portable Recorder

Bulletin 60-100 on instrument for recording any measurement that can be converted to a change in resistance of d.c. millivoltage. *Thermo Electric*

1453. Potentiometer

New 64-page bulletin P1245A on electronic potentiometer and bridge instruments for recording and controlling. Instruments and components, principles of operation, specifications. Equipment in which they are incorporated. *Bristol Co.*

1454. Powder Metallurgy

12-page bulletin B-101 on furnaces for sintering powder metal products and reduction of metallic oxides. *Drever Co.*

1455. Powdered Iron

Properties of Past/Iron with and without copper. *Plastic Metals Div.*

1456. Powdered Metals

12-page brochure describes and illustrates process of making parts; assembly and finishing operations. Case histories. *Powdered Metal Parts Div., Lux Clock Mfg. Co.*

1457. Powdered Metals

24-page booklet on sintered bronze bearings and metal parts. Design hints, machining suggestions. Specifications. *Bunting Brass and Bronze*

1458. Powdered Metals

Booklet on design, properties, production and application of brass and other nonferrous powder parts. 24 case histories. *New Jersey Zinc*

1459. Precision Casting

12-page book on alloy selection and design for investment casting. *Arwood Precision Casting*

1460. Precision Casting

12-page book tells when to use precision castings, tolerances, how castings are made. *Alexander Saunders*

1461. Precision Casting

8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1462. Press Brakes

New 4-page bulletin No. 57PR on heavy duty steel press brakes. Principal features, specifications and capacities of 40 standard sizes. *Dreis & Krump Mfg. Co.*

1463. Presses

8-page bulletin on new straight side crank-type press. Standard specifications. *Hamilton Div., Baldwin-Lima-Hamilton*

1464. Presses

New 40-page booklet on power operated machines for plate and sheet metal work. Specification charts. *Niagara Machine & Tool Works*

1465. Presses

Data on mechanical and hydraulic powered metal presses 8 to 500-ton capacities. *Haller, Inc.*

1466. Product File

30 new products and 500 pieces of literature described in 20-page reprint of items appearing in monthly magazine during first quarter, 1957. *Metal Progress*

1467. Protecting Tubes

New bulletin 1000-56 on ceramic protecting tubes lists sizes and materials. *Claud S. Gordon*

1468. Pyrometer

Catalog No. 100 on radiation pyrometers with ranges from 1000 to 3400° F. *Pyrometer Instrument Co.*

1469. Quenching

64-page book tells what happens when steel is heated and cooled, describes quenching media, quenching practices, interrupted quenching and cooling methods. *E. F. Houghton*

1470. Radiography

28-page booklet on products for industrial radiography gives exposure and processing data for various films used. *DuPont, X-Ray Div.*

1471. Rare Earths

8-page Progress Report Number 1, "Rare Earths in Iron and Steel Melting". *Molybdenum Corp.*

1472. Refractories

Bulletins 320 and 321 on super-refractory for service to 3350° F. and heat-setting foundry patch. *Chas. Taylor Sons*

1473. Refractories

24-page booklet on how refractory grain is produced. Chemical and physical characteristics, sizes available, applications. *Norton*

1474. Refractories

Data sheets on high-alumina, chrome, lightweight and extra-strength castable refractories. *Harbison-Walker*

1475. Refractories

40-page book lists super-refractories for heat treating furnaces and gives data on use in different kinds of furnaces. *Refractories Div., Carborundum*

1476. Resistance Material

New 16-page brochure on high-temperature electrical resistance heating mate-

(Continued on page 48-A)

Save by using specialized refractories

Many refractories problems in metal-working furnaces have been solved *economically* by the use of B&W specialized refractory castables. Each ferrous or non-ferrous furnace application requires a specific combination of properties to meet the service conditions. Whether your problem is high temperatures, abrasion and erosion, slag attack or the need for insulation, to name a few, you will find the refractory castable best suited to your requirements in B&W's line. Shown here in digest form are data on the widely used B&W refractory castables for metal-working furnaces:

B&W Refractory Castables for Metal Working Furnaces

	Temp. F	PROPERTIES	TYPICAL APPLICATIONS
B&W Kaocast	3000	High resistance to spalling and slag attack. Low volume change and negligible reheat shrinkage.	Soaking pit covers, linings of high temperature heating and forging furnaces, burner blocks, electrode linings of electric furnace roofs, linings of non-ferrous metal furnaces.
B&W Kaocrete 32	3200	High strength, exceptional refractoriness, unusual volume stability, excellent resistance to spalling.	Can be used in applications similar to those of B&W Kaocast and where higher refractoriness is required.
B&W Kaocrete D	2500	Sufficient strength and hardness to withstand abrasion, considerable physical abuse and erosion.	Aluminum melting furnaces, linings and car tops in heat treating furnaces, as well as in sections of a wide variety of furnaces that are subject to scraping by hand tools or other mechanical abuse.
B&W Kaocrete A	2600	Resists reducing atmospheres. Has good resistance to erosion, abrasion and thermal shock.	Annealing furnace bases and other applications where resistance to reducing atmospheres is essential. Also as a general purpose castable for linings in medium temperature service.
B&W Kaocrete B	2300	Has an adhesive plastic texture particularly suited for vertical or overhanging constructions. Excellent for plastering.	Patching linings and baffles and for any application where plastering rather than gunning or casting is required.
B&W Kaocrete LI	2700	High alumina content, exceptionally high strength for resistance to abrasion and erosion.	Aluminum furnace linings where high alumina content is important.
B&W Kaolite 20	2000	Offers castable's fast, low cost installation plus insulation. Has refractoriness, light weight and low heat conductivity and, in addition, will resist reducing atmospheres. Can be poured or gunned.	Aluminum melting, heating and heat-treating, annealing and forge furnaces. Also for general maintenance and patching.
B&W Kaolite 22	2200	Has the same properties as B&W Kaolite 20. Can be used for higher temperatures but not in reducing atmospheres.	

Send for your copy of B&W Bulletin R-35. It gives additional information on B&W's versatile refractory castables.

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(Continued from page 47)

rial. Electrical, chemical and physical characteristics of new cermet material. *Kanthal Corp.*

1477. Resistance Welding
New special machine bulletin on 32 multi-spot and projection resistance welding machines. *Taylor Winfield Corp.*

1478. Rhodium Plating
Data on properties, thicknesses required, costs, operation, applications. *Technic*

1479. Salt Bath Furnace
Bulletin 655 on immersed electrode salt bath furnace gives advantages, applications, construction. *Hevi Duty*

1480. Salt Balt Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

1481. Salt Baths
Reprint No. 149 on salt bath furnace treatment of landing gears. Equipment used, advantages. *Ajax Electric Co.*

1482. Sand Systems
Bulletin No. SL-3 shows layout of system and controls. *Harry W. Dietert Co.*

1483. Sawing Titanium
File sheets give experiences in sawing different titanium alloys. Procedures and recommendations. *DoAll Co.*

1484. Selective Carburizer
Bulletin on "No-Carb" for selective carburizing and prevention of decarburizing on high alloy steels during heating for hardening. *Park Chemical*

1485. Selective Strippers
Bulletin on materials for selective stripping of one metal from another—electroplated metals, solder or brazing excess. *Enthone*

1486. Silver Brazing
8-page Bulletin B-80 on low temperature silver brazing alloy. Joint preparation, strength of brazed joint, ductility and corrosion resistance. *United Wire and Supply Corp.*

1487. Sintered Carbides
24-page booklet on the characteristics of the various grades, for research and design engineers. *Kennametal*

1488. Smelting Equipment
48-page booklet 105 on equipment for smelting covers complete furnaces, electrodes and control equipment. *Pittsburgh Lectromelt*

1489. Sodium
40-page booklet on handling metallic sodium gives typical sodium-using processes, equipment installation, recommendations for pumping and instrumentation. *U. S. Industrial Chemicals*

1490. Spectrographic Sources
4-page bulletin 35A on spectrographic source unit gives data on three units available. *Baird Assoc.*

1491. Spray Painting
16-page bulletin on electrostatic spray painting. How it is done. Case histories. *Ransburg Electro-Coating Corp.*

1492. Springs
8-page bulletin on spring design. Stress and deflection formulas for various types of springs. Physical properties of commonly used spring materials. *Associated Spring*

1493. Stainless Castings
Bulletin on advantages of corrosion-resistant castings. *Ohio Steel Foundry*

1494. Stainless Castings
20-page booklet shows how they are made, property and size data, typical applications. *Crucible Steel*

1495. Stainless Fasteners
New 24-page catalog 56-A lists sizes and types. 7000 items included. *Star Stainless Screw*

1496. Stainless Steel
20-page catalog on corrosion resistance, applications and working characteristics of 20% chromium-29% nickel stainless steels, with and without columbium. *Carpenter Steel*

1497. Stainless Steel
16-page booklet on Type 430 stainless gives physical properties and analysis, corrosion resistance, fabrication, application and care. *Washington Steel*

1498. Stainless Steel
36-page bulletin on effect on properties of processing at different temperatures. *International Nickel*

1499. Stainless Steel
Two booklets on 200 series of low nickel, austenitic stainless steels, give applications and properties compared with 300 series. *Republic Steel*

1500. Stainless Steel
12-page booklet on precipitation hardening stainless steel. Mechanical properties after various heat treatments. *Electric Steel Corp.*

1501. Stainless Steel
Data sheet on Type 301 gives physical properties, corrosion and oxidation resistance, mechanical properties. *Allegheny Ludlum*

1502. Stainless Tubing
New 4-page bulletin 17-7PH stainless pipe. Tubular forms, analysis, uses, properties, workability, hardening characteristics. *Carpenter Steel Co.*

1503. Steel
Bulletin on Yoloy C, corrosion resistant low alloy steel. Chemical analysis and properties. *Youngstown Sheet and Tube*

1504. Steel Bars
Folder gives machinability of C-1144 strain-tempered steel. *Bliss & Laughlin*

1505. Steel Bars
10-page bulletin on cold-worked, furnace treated steel bars. Properties, analysis, advantages. *LaSalle Steel Co.*

1506. Stress-Strain Recorders
28-page bulletin No. 4215 on 16 standard recorders and 50 models of strain followers, for use on standard testing machines. *Baldwin-Lima-Hamilton*

1507. Sub-Zero Treatment
12-page booklet on industrial chilling equipment for shrinking, testing and treating of metals. *Cincinnati Sub-Zero Products*

1508. Surface Temperature
Bulletin No. 4257 on Pyrocon, surface temperature instrument. *Illinois Testing Laboratories*

1509. Swaging Machines
16-page catalog on complete line of swaging equipment contains data on rotary swaging process and its applications. *Fenn Mfg. Co.*

1510. Temperature Measuring
Bulletins on Tempilstiks and Tempilaq describe products and tell how to use them. *Tempil® Corp.*

1511. Test Specimens
Data on machine for cutting test specimens to ASTM specifications. *Sieburg Industries*

1512. Testing Machines
12-page catalog on ten testers including hardness, ductility, tensile, compression and transverse strength. *Detroit Testing Machine*

1513. Testing Machines
24-page Bulletin 47 on complete line of Super "L" universal testing machines. Indicating systems, loading systems, diagrams of various machines. *Tinius Olsen Testing Machine*

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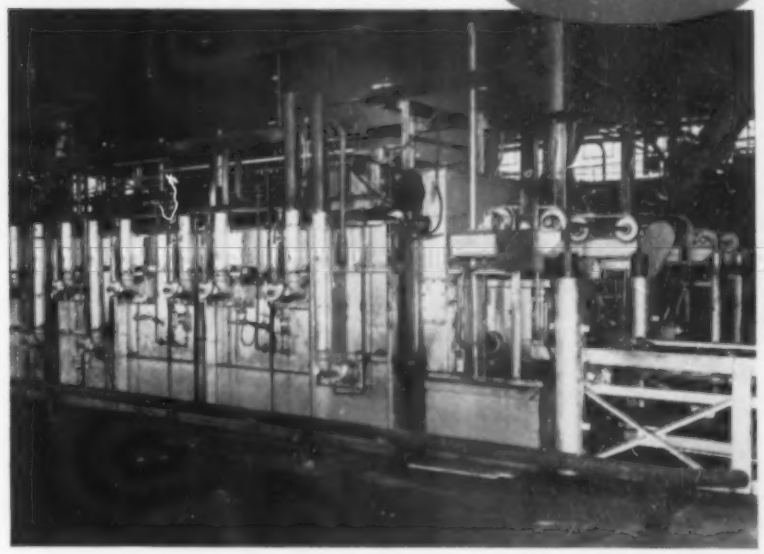
BLAZING THE HEAT TREAT TRAIL WITH HOLCROFT



LET'S TALK ABOUT

PRODUCTION DEMANDS

High production demands can be met only when every piece of equipment in the plant is geared to its job. In many plants, the bottleneck is heat treating because furnaces which were modern five years ago are virtually obsolete. These units must be replaced, redesigned, or added to.

Automatic handling of materials is one answer, of course. Today, some heat treating systems are tied right into production lines. In other plants, work is centralized with automated equipment eliminating most stock handling. A single operator loads green work and removes finished parts.

Some furnaces accomplish dual jobs. A recent Holcroft installation was built to temper two entirely different classes of carburized parts. The furnace was designed with a double chamber with each side operating at the required temperature. Flags, placed on the trays requiring low temperature tempering, keyed the line so that the work automatically positioned itself in front of the correct chamber. Another installation featured a double deck furnace—designed so that two entirely different heat treat processes were accomplished in space where but a single furnace would normally go.

And so it goes: a little idea to save a minute or to eliminate a manual operation—a brainstorm that combines two or more furnaces or steps up furnace capacity. This Holcroft concept can help you produce more for less and with better quality. Better write today.

6030

HOLCROFT AND COMPANY
6545 EPWORTH BOULEVARD • DETROIT 10, MICHIGAN
PRODUCTION HEAT TREAT FURNACES FOR EVERY PURPOSE

CHICAGO, ILL. • CLEVELAND, OHIO • HARTFORD, CONN. • HOUSTON, TEXAS • PHILA., PA.
CANADA: Walker Metal Products, Ltd., Windsor, Ontario

48-A

CMP

RESTRICTED SPECIFICATION COLD ROLLED STRIP STEEL

for Spring Steel Requirements such as these . . .

FORMED PARTS FOR HEAT TREATMENT

SIZE	8 x .036
ANALYSIS	1050
FINISH	Bright
HARDNESS	Rockwell B-78 Max.
THICKNESS TOLERANCE	± .0003 incl. crown
WIDTH TOLERANCE	± .005
MICROSTRUCTURE	Uniform spheroids
COIL SIZE	16" I.D. coils large as possible
PACKAGING	On skids — shrouded

FLAT PARTS FOR HIGH STRENGTH WITHOUT HEAT TREATMENT

SIZE	18 x .020
ANALYSIS	1075
FINISH	Bright
HARDNESS	Rockwell C-30 Min.
THICKNESS TOLERANCE	± .001 incl. crown
WIDTH TOLERANCE	± .005
MICROSTRUCTURE	Small-fine carbides
COIL SIZE	16" — I.D. Max. coil wt. 1000#
PACKAGING	On skids — shrouded

SIZE	14 x .040
ANALYSIS	1095
FINISH	Bright
HARDNESS	95 to 105 Rockwell B suitable for blanking
THICKNESS TOLERANCE	± .0005 incl. crown
WIDTH TOLERANCE	± .005
MICROSTRUCTURE	Uniform medium size spheroids
COIL SIZE	16" — I.D. Max. coil wt. 600#
PACKAGING	On skids — shrouded

Knowing exactly what you require for most efficient fabrication and most effective product performance, CMP can set up and consistently meet restricted specifications to match your most exacting demands. Often production operations can be greatly simplified or even eliminated; in most instances end-product and/or assembly costs can be reduced and quite frequently, product quality improved.

We would welcome an opportunity to explore with you the possibilities of CMP Restricted Specifications applied to your strip steel requirements.

FOR 3 IN 1 SERVICE ON YOUR COLD ROLLED STRIP STEEL

Now there are three CMP plants with facilities for production of "Restricted Specification" cold rolled strip. Strategic locations at Youngstown, Indianapolis and Los Angeles, provide the security of 3 sources of supply plus the close working relationship which these local production centers make possible.

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PLANTS: YOUNGSTOWN, INDIANAPOLIS AND LOS ANGELES
SALES OFFICES: NEW YORK - CLEVELAND - DETROIT - INDIANAPOLIS
CHICAGO - LOS ANGELES - SAN FRANCISCO

1514. Testing Machines
28-page catalog on screw power universal testing machines and accessories. Construction, specifications. *Riehle*

1515. Textured Metal
16-page booklet on advantages and applications of textured metal. *Rigidized Metals*

1516. Thermocouple Alloys
20-page booklet on chromel-alumel alloys gives sizes, temperature-millivolt equivalents, standards, applications. *Hoskins Mfg.*

1517. Thermocouples
44-page catalog EN-S2 describes couples and assemblies for general application and for special plant and laboratory uses. Tubular data on accuracy and limits of couples. *Leeds & Northrup*

1518. Thermocouples
20-page Bulletin 714 on thermocouples, protecting tubes and wells, insulators, leads, connectors, heads. *Gen. Electric*

1519. Thickness Gage
Folder on pocket-size gage. How to use it. *Ferro Corp.*

1520. Thickness Tester
Data sheets give ranges, principle of operation of nondestructive thickness tester. *Unit Process Assemblies*

1521. Titanium
Folder on commercially pure, unalloyed titanium gives properties, types supplied, forming methods, cleaning. *Mallory Sharon Titanium*

1522. Tool Steel
Wall chart showing more than 300 varieties of tool steel with trade name of manufacturers. *Vulcan Crucible Steel*

1523. Tool Steel
Data sheets on high speed, hot work, air, oil and water hardening tool steels, alloy steels, machinery steels, stainless steels, welding rods. *Crucible Steel*

1524. Tool Steel Color Guide
Color guide to estimate temperatures has heat colors on one side and temper colors on the other. *Bethlehem Steel*

1525. Tool Steels
Bulletin on tool steels, hot work specialty steels, bar stock, billet, sand casting, drill rod, flat ground stock and tool bits. *Darwin & Milner, Inc.*

1526. Tool Steels
13-page directory of tool and die steels gives SAE designations with compositions, properties, forging and heat treating data, trade names. *Cannon-Muskegon Corp.*

1527. Tubing
New 64-page handbook on use of tube mills in manufacture of pipe and tube. Step-by-step description of the electric-weld process. *Yoder Co.*

1528. Tumbling Materials
Data on limestone chips, red granite chips, aluminum oxide, special honing, burnishing, abrasive compounds. *Universal Tumbling Supply*

1529. Ultrasonic Cleaner
Discussion of ultrasonic cleaning and an ultrasonic cleaner for metallography, in Metal Digest, Feb. 1957. *Buehler*

1530. Ultrasonic Inspection
Ultrasonic Inspection Newsletter, No. 2, contains article on immersion inspection of wing spars for jet fighters. *Sperry Products*

1531. Ultrasonic Machining
16-page bulletin lists typical machining operations, materials which may be machined ultrasonically, machine features and accessories. *Sheffield Corp.*

1532. Ultrasonic Testing
6-page folder on immerscope diagrams instrument and tells how it may be used. *Curtiss-Wright Corp.*

1533. Ultrasonics
Bulletin on ultrasonic generator describes transducers, controls, specifications. *General Ultrasonics Co.*

1534. Ultrasonics
Data sheet on gages for thickness measurement, coating measurement, inspection. *Branson Instruments*

1535. Vacuum Coating
Bulletin on principles, production steps, applications, equipment. *National Research*

1536. Vacuum Metallizing
Bulletin 780 gives uses and advantages of vacuum metallizing, materials and properties of vacuum metallized coatings, the process, equipment. *Stokes*

1537. Vacuum Metallurgy
Information memo describes the high-vacuum technique and pumping systems. *Consolidated Vacuum Corp.*

1538. Vacuum Metals
File of data on vacuum-melted metals and their applications for bearings and the chemical industry. Development of the vacuum metals. *Vacuum Metals Corp.*

1539. Vacuum Pumps
52-page catalog No. 425 on high-vacuum pumps contains formulas and tabular data. *Kinney Mfg.*

1540. Welding
12-page booklet on three-phase resistance welding machines. Operational principles, associated control equipment. *Taylor-Winfield Corp.*

1541. Welding
12-page reprint tells of welding procedures in fabrication of crosshead beams for large forging press. *Linde*

1542. Welding
24-page booklet on electric resistance welding of butane gas containers. Procedures, metallurgical advantages. *Sciaky Bros., Inc.*

1543. Welding
Data on welding positioners from 500 to 100,000 lb. capacity. *Harnischfeger*

1544. Welding Alloy Steel
44-page Data Book 4D covers all types of welding of nickel alloy steels. *International Nickel*

1545. Welding and Cutting
6-page reprint on mechanized oxygen cutting and electric welding, including inert-gas-shielded processes and iron powder electrodes. *Air Reduction*

1546. Welding Chart
Wall chart gives instructions on use of electrodes, proper welding procedure, types of joints, standard steel shapes. *Hobart Brothers Co.*

1547. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

1548. Wire Cloth
84-page booklet on applications, meshes, baskets, filters. *Cambridge Wire Cloth*

1549. X-Ray
12-page bulletin on gamma radiography tells how to select the source, equipment, techniques and fundamentals of gamma radiation. *Picker X-Ray*

1550. X-Ray Supplies
Bulletin on X-ray films and chemicals for radiography. *Ansco*

1551. Zirconium
8-page brochure on zirconium's corrosion resistance properties. Applications based on this property. *Carborundum Metals Co.*

1552. Zirconium
4-page folder gives properties, specifications and fabrication of reactor-grade zirconium. *Columbia-National Corp.*

MAY, 1957

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1242	1268	1294	1320	1346	1372	1398	1424	1450	1476	1502	1528	
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1244	1270	1296	1322	1348	1374	1400	1426	1452	1478	1504	1530	
1245	1271	1297	1323	1349	1375	1401	1427	1453	1479	1505	1531	
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SOME that you know of — the cost of handling, the space it requires, and the melting loss you've already figured on.

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ARMASTEEL®

ArmaSteel is a versatile pearlitic malleable iron that combines the advantages of both castings and forgings. ArmaSteel parts can be cast by conventional sand method or shell mold process to relatively close dimensions in large quantities at low cost. Because of the excellent, accurately controlled physical properties of ArmaSteel, these parts have the strength and performance characteristics usually associated with plain carbon steel forgings.

ArmaSteel is produced in three ranges: ArmaSteel 84M, ArmaSteel 85M and ArmaSteel 86M with a wide variety of physical properties uniformly maintained through accurate heat treating operations as follows:

ARMASTEEL 84M is recommended where a high degree of strength is necessary. It usually replaces heat-treated steel parts in the 1040-1050 S.A.E. range. It has a hardness range of BHN 241-269 or 3.7-3.9mm. impression with a 3000 Kg. load. Tensile strength is 100,000 p.s.i., yield strength is 80,000 p.s.i., and percent of elongation in 2" is 2.0%.

ARMASTEEL 85M is recommended where moderate strength is required and where selective hardening is necessary. This class usually replaces parts in the 1035-1050 S.A.E. range. It has a hardness range of BHN 197-241 or 3.9-4.3 mm. impression with 3000 Kg. load. Tensile strength is 80,000 p.s.i., yield strength is 60,000 p.s.i., and percent of elongation in 2" is 3.0%.

ARMASTEEL 86M is recommended for less highly stressed parts usually replacing steel parts in the 1020-1035 S.A.E. range. It has a hardness range of BHN 163-207 or 4.2-4.7 mm. impression with 3000 Kg. load. Tensile strength is 70,000 p.s.i., yield strength is 48,000 p.s.i., and percent of elongation in 2" is 4.0%.

MACHINABILITY OF ARMASTEEL

ArmaSteel's machinability makes it outstanding in the ferrous field. In general, its rating is from 10% to 30% better than bar stock or forgings of the same Brinell hardness. One of the reasons for this rating is the structure, which consists of a matrix of sorbitic- pearlite and spheroidized cementite in which small nodules of carbon

a triumph of modern metallurgy

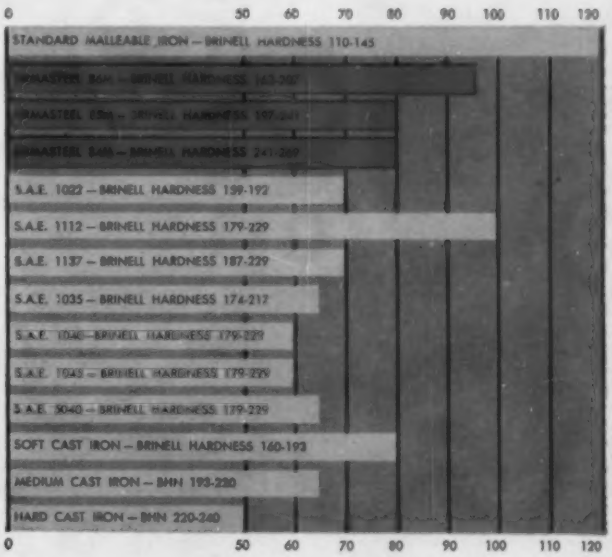
are imbedded. Because of this the chips break off more readily in machining operations whether it be turning, drilling, milling or broaching.

The machinability rating of a metal is not absolute—its rating can be stated only in relation to that of another metal. To establish the accompanying machinability rating table Bessemer screw stock S.A.E. 1112 is used as the base. In establishing these ratings, the cutting speed of the S.A.E. 1112 is the rate generally used in turning this metal on automatic screw machines. The rate of feed, however, is altered to that necessary to attain normal tool life and good surface finish when using a coolant. When the other metals are tested, the feeds and speeds are varied from these basic rates to whatever rate is necessary to obtain comparable tool life and comparable surface finish. The ratio of these rates of speeds and feeds of each tested metal determines the percentage of machinability.

The FIVE parts illustrated below are typical of the hundreds of different parts and products successfully produced in ArmaSteel for many diversified industries.

Write, today, for new 70 page comprehensive catalog.

MACHINABILITY RATING (PER CENT)



CENTRAL FOUNDRY DIVISION · GENERAL MOTORS CORPORATION

50-A

CENTRAL FOUNDRY DIVISION
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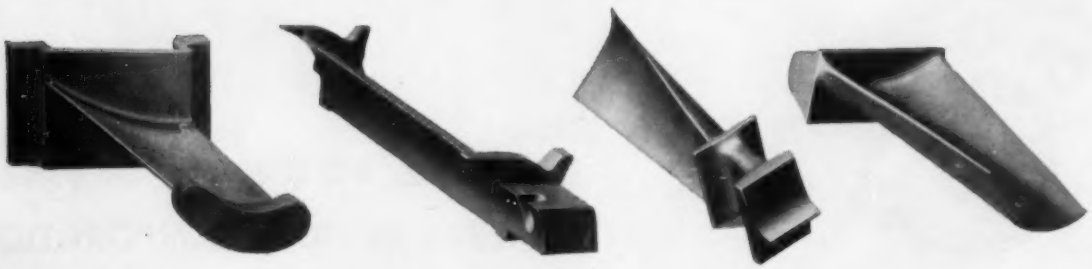
SAGINAW, Dept. 19, MICHIGAN

Typical precision castings which Austenal, Inc., Microcast Division, plans to produce with new Stokes Model 437-520 vacuum furnaces.



Here's a Really New Vacuum Furnace

for "all-out" production of precision castings

Stokes precision casting furnaces—capable of melting and pouring single casts of up to 30 pounds, under vacuums as low as 1 micron or less—are custom-designed and engineered to incorporate many operating features specially requested by precision casters. Units are in operation with charging and mold locks for semi-continuous production.

This low-cost "package" unit:

- pours smoothly... has a manually-operated tilting mechanism that operates easily.
- has good visibility . . . operator watches pour closely through 3-inch diameter shuttered sight glass.
- is easily operated . . . efficiently grouped controls cut operator's movements. Popular tandem units are operated by one man.
- can be set up for repetitive pre-determined melting and pouring cycles . . . interlocked, fail-safe controls permit operation by a normally skilled workman.
- provides accurate control over pouring temperatures . . . regularity of heat cycles cuts gage-watching time.
- takes up little floor space . . . measures 6'10" wide, 7'3" deep.

Others are taking advantage of Stokes advanced vacuum furnace technology in induction and arc melting, heat-treating and sintering. Isn't it time for you to contact Stokes for a discussion of your own profit-making opportunities?

Vacuum Equipment Division
F. J. STOKES CORPORATION
5500 Tabor Road, Philadelphia 20, Pa.

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STAINLESS STEEL

PRESSURE
HEAT EXCHANGER, CONDENSER AND EVAPORATOR —Full Range of Sizes
PRESSURE
PIPING—Complete Range of Schedules. 40, 10 and 5 Sizes
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SANITARY—O.D. and I.D. Polished—For Dairy and Food Processing
PRESSURE
HEAT RESISTANT—Special Analyses 300, 300S, 310, 330
PRESSURE
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BEVERAGE—Cut Lengths or 50' Coils

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SPECIALTY WELDED TUBING

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Republic, the pioneer in this improved welding technique, is proud of its many "firsts" in the industry. In addition to introducing ELECTRUNITE® Boiler Tubes to the trade more than 25 years ago —plus Electrical Metallic Tubing and Dekoron®-Coated E.M.T. to the electrical industry, Republic was the first to provide a non-destructive electronic production method of testing tubing used for critical pressure applications, known to the trade as FARROWTEST®.

With plants in four locations, we are able to service you promptly with these complete ranges of analyses of carbon and stainless steels for mechanical, structural and pressure uses. A wide selection of sizes for every tube is also available. (See captions.)

Next time you need tubing or electrical raceways, whatever the application, call your nearest Steel and Tube Representative. Or contact us direct. We've solved a lot of problems in 50 years, and we'll be happy to tackle yours. To get descriptive literature, mail coupon at right.

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REPUBLIC STEEL

World's Widest Range of Standard Steels

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CARBON STEEL TUBING

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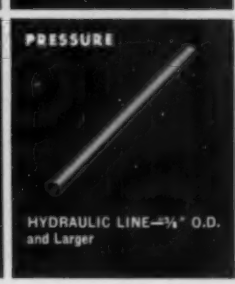

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N-A-X HIGH-TENSILE is readily formed and welded. Here, before welding, a worker sizes the container's aft head, drawn by a 250-ton press. Bottom forging is locked in.

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Formability: Even at the higher strength levels (50% greater than mild carbon steel) this material can be cold formed and drawn into very difficult stampings and cold formed shapes.

Weldability: Its weldability by any process is excellent, maintaining toughness through a wide range of temperatures. Under-bead cracking tests are excellent. Using American Welding Society standard bead-weld testing, shows under-bead hardness rises only to 95 Rockwell from 80-85 Rockwell prior to welding.

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N-A-X FINEGRAIN. A low-alloy high-strength steel ideally suited for applications where the enhanced resistance to atmospheric corrosion of N-A-X HIGH-TENSILE is not required.

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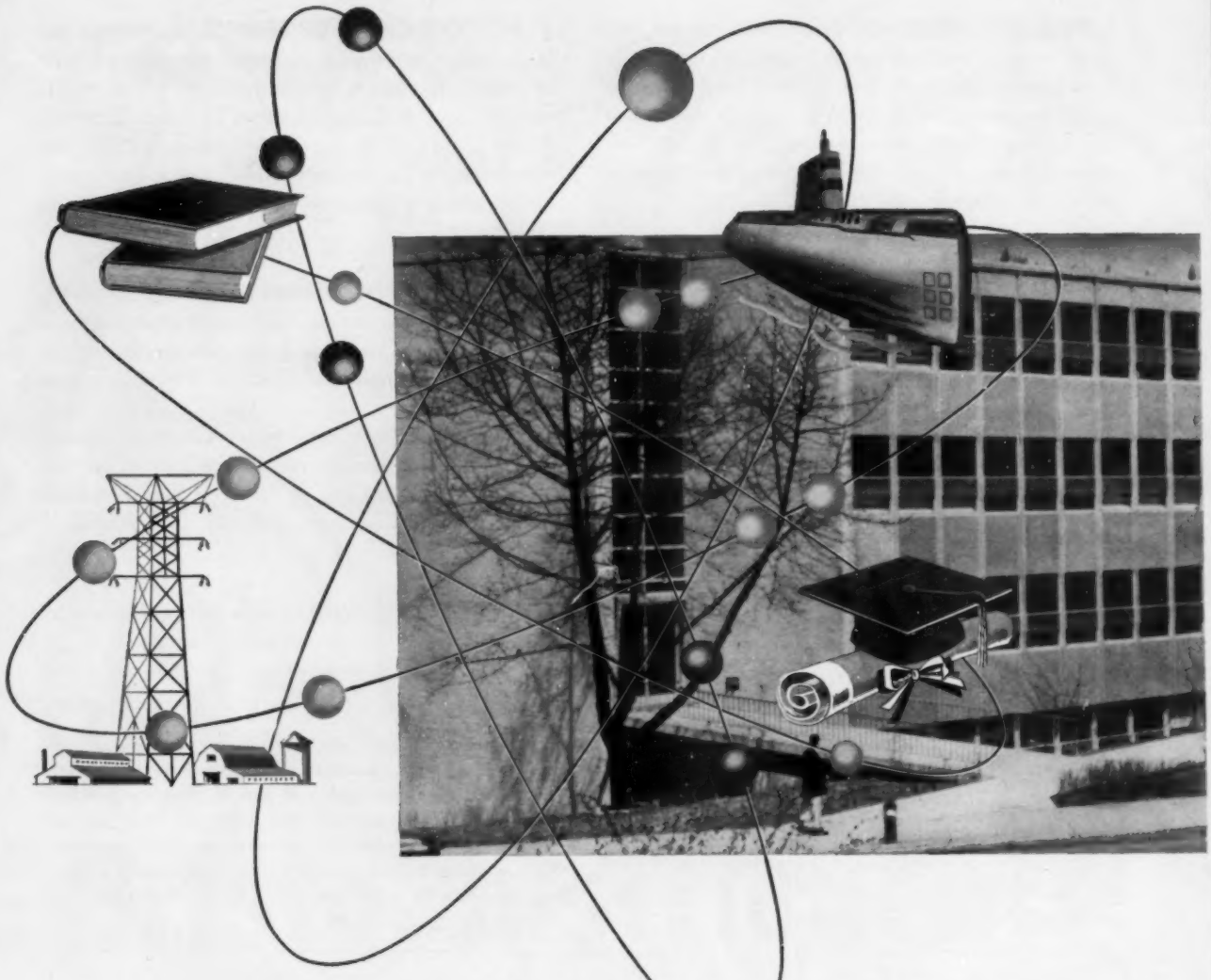

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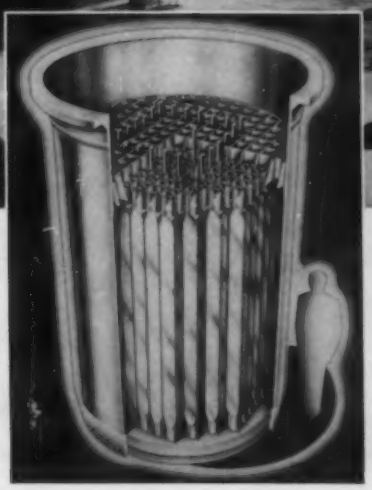

The reactor core for the Shippingport Atomic Power Station

metallurgical engineers

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The floor charging machine at left is loading an ingot into a heating furnace. At right is the control panel with ***ElectroniK*** strip chart program controllers.

ElectroniK program controllers automatically regulate soaking and cooling furnaces. These furnaces are also equipped with Honeywell multiple burner ***Protectoglo*** flame safeguard systems. The control cabinet of one of these systems is shown at upper right.

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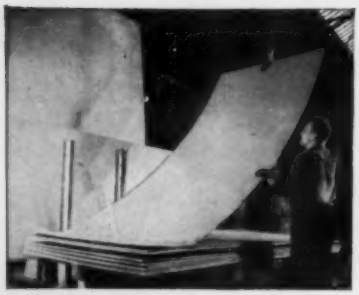

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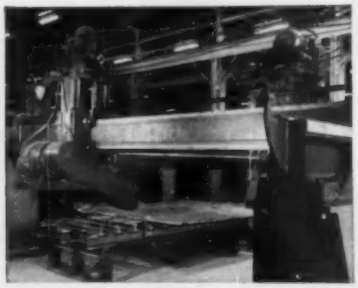

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Metal Progress
Volume 71, No. 5 May 1957

Metals for Fast Flight

Many sessions of the Western Metal Congress discussed metals for airframes, not alone for those going twice the speed of sound, which we have now, but strong enough for the 2400 mi. per hr. anticipated in 1970. The latter is unknown at present. Even the alloys which nearest approach it are so intractable that entirely new fabrication techniques will have to be developed. (T24a, SGA-h, SGB-a)

THE Tenth Biennial Western Metal Congress easily surpassed its predecessors. The Exposition also was a record breaker in many respects: The area, 184,800 sq. ft., occupied the entire Pan-Pacific Auditorium plus four pavilions (circus tents). The exhibiting firms numbered 351. Their exhibits were informative and attractive. The clocked attendance for the five days was 73,858 with a crowded 30,243 on Wednesday alone! No question about it, Southern California has become one of America's major industrial centers.

J. L. McCloud, *Metal Progress*' consulting editor, pronounced this Congress "outstandingly good." Its program was for the most part arranged locally, and hence should truly reflect the interests of the region. Success was largely due to Wm. V. Ward, research engineer, Lockheed Aircraft Corp., Burbank, who served as general chairman. Five of the sessions were devoted to structures for "thermal flight", eight to materials, fabrication and joining of airframes, seven to nondestructive testing, and eight to other topics – largely welding. These figures do not include the ten meetings of the Titanium Conference, the first ASM Seminar ever to be held, and whose success encourages the belief that it ushers in a new and important activity of the American Society for Metals. The above total of 28 does, however, include the meetings of the four other national societies which cooperated in the Congress.

In view of the wealth of material presented and time and space limitations, this account in *Metal Progress* will be confined to a review of meetings which considered properties of materials for aircraft and missiles, and new methods of forming and fabrication. Some of these papers will be published in full in future issues; some will be added to the account of the Albuquerque Conference on Heat Tolerant Metals for Aerodynamic Applications.* Some information derived from meetings of the American Welding Society will be added to an account

*Held Jan. 28 and 29 by Albuquerque and Los Alamos Chapters ASM and the University of New Mexico. Proceedings are being edited for publication as a book by the Society.

of that Society's April meeting in Philadelphia to be printed in the next issue of *Metal Progress*. The full program of the Society for Nondestructive Testing will be available from that Society (Philip D. Johnson, secretary, 1109 Hinman Ave., Evanston, Ill.). Finally the papers on brazing and soldering presented by the Industrial Heating Equipment Association will be printed in *Metal Progress* in July and August.

Requirements for Fast Flight

Two years ago the Editor wrote in Critical Points that speeds of military aircraft were getting so high that the pilot did not have time to pilot; he had to rely on electronic and mechanical devices for reaching the target and firing at it. "Speed" in that sentence meant about Mach 2 – twice the speed of sound. Really fast flight (now dubbed "thermal flight") on the order of Mach 5, at 20 miles altitude and more than 10 min. duration, is now concerning the designers, and was discussed by a panel led by Alfred H. Petersen, group engineer of methods, Lockheed Aircraft Corp. of Burbank, on "Aircraft Alloys for Thermal Flight to 1200° F."

Leo Schapiro, chief metallurgist for Douglas Aircraft Co., Santa Monica, led off with an arresting presentation in which he showed that the speed of fastest aircraft, type by type, since World War I has a straight-line relationship when year is plotted against speed. In another plot (also a straight line but rising at a steeper slope) he gave the strength-weight ratio of the best materials available for each of these aircraft. This ratio he called the "index", since it is the quotient of *yield* strength in lb. per sq.in. divided by density in lb. per cu.in. Extending these lines to where speed will cause thermodynamic heating to 1200° F., he concluded that we would then need metal of 800,000 "index".

Such a requirement immediately excluded the best of the magnesium, aluminum or titanium alloys which have no structural use at 1200° F. The 17-7 nickel-chromium steels, precipitation hardened, have a "Schapiro index" of only 650,000 at 600° F. and 550,000 at 800° F., so they are clearly inadequate for the requirement at 1200° F., even if we grant they may be considerably improved by new steelmaking or heat treating techniques. R. B. Gunia, assistant manager of stainless steel metallurgy for U.S. Steel Corp., Pittsburgh, said that his firm is intensively studying quenched and tempered steels since the martensitic microstructure can have the highest tensile strength for a given amount of ductility; he consequently was very hopeful that a 12% chromium steel, heat treated to 230,000 psi. at room temperature, would have important applications. He gave no figures for the yield at 1000° F., but on the assumption that it could be as high as 185,000 psi., its "index" of 675,000 at 1000° F. is still far short of the desired 800,000 at 1200° F.

George A. Roberts, vice president – technology, Vanadium-Alloys Steel Co., Latrobe, Pa., presented an argument for hot die steel, material best known to the metallurgist as heavy block-like masses, although toolsteel sheet and strip has been long available, 0.025-in. sheet having been rolled 24 in. wide by 95 in. long. His associate, J. C. Hamaker, Jr., has described one of these die steels rather fully in *Metal Progress* for December 1956. Its analysis is 0.40% C, 5.0% Cr, 1.3% Mo and 0.5% V. It is about the lowest alloy steel which has a pronounced secondary hardening effect (a maximum of hardness after a relatively high draw) and therefore can be expected to maintain its strength well at temperatures below 950° F. Hamaker quotes yield strength of 166,000 at 900° and 63,000 at 1200° F. ("indexes" of 600,000 and 230,000 at the respective temperatures). These are so much lower than the anticipated requirements that the improvements from raising the carbon content and making other alloy additions, such as tungsten or cobalt mentioned by Dr. Roberts, can hardly bridge the gap. Strong steel of this sort is hard – between C-50 and C-55 on the Rockwell scale – and will require entirely new techniques for shaping and cutting. It is not corrosion resistant, but laboratory work was mentioned on a hot dipped aluminum coating which gave a very adherent layer 0.004 to 0.006 in. thick and C-40 to 44 hard.

The merits of high-nickel alloys were not detailed at this meeting but figures can be taken from a paper presented to several ASM Chapters last winter by Alan V. Levy, chief of the materials and process section of Marquardt Aircraft Co. of Van Nuys. Various "Inconels" and (British) "Nimonics" have long been used in jet engines, Inconel "X" (73 Ni, 15.0 Cr, 7.0 Fe, 2.5 Ti, 1.0 Cb, 0.7 Al) being the usual material for after-burner combustion chambers reaching 1600° F. V. N. Krivobok, in charge of stainless and heat resistant alloy development for International Nickel Co., New York City, said that a new sheet alloy known as Inco 700 seems to have outstanding merit at the high temperatures.

It is similar to Inconel "X" but has a considerable proportion of the nickel replaced by cobalt and molybdenum. Levy's data indicate that the "index" at 1200° F. is 255,000 for Inconel "X" and 300,000 for Inco 700.

The best of the so-called superalloys described by F. S. Badger, vice-president of Haynes Stellite Co., Kokomo, Ind., could also be included in the category of high-nickel alloys. These superalloys have been used principally for jet engine blades where they operate several hundred degrees higher than the 1200° F. called for in this panel discussion. Some of them have never been produced in sheet form or even as forgings. They are heavier than the lower alloyed irons; nevertheless Mr. Badger suggested that some of the forgeable analyses after cold work and aging might come closest to Mr. Schapiro's desired index figure at 1200° F. Some unexpectedly high values have recently been found for Haynes Alloy No. R-235 (62.0 Ni, 15.5 Cr, 10.0 Fe, 5.5 Mo, 2.5 Co, 2.5 Ti, 2.0 Al) cold worked 20% and aged at 1200° F. The "index" for material in such condition is 450,000 at 1200° F. Tensile ductility, cold, of such sheet is 20%, which indicates reasonably good formability. It will soon be produced commercially in sheets 48 in. wide.

While the latter figure is the best mentioned at the meeting, the discussion really indicated that *no* metallic alloy is in sight which will meet Mr. Schapiro's request for an 800,000 index at 1200° F. Therefore, he was asked the question: "Where do we go from here?" He replied briefly that since his ascending lines showing aircraft speeds in past years were dependent also on more and more powerful and efficient power plants, one way out of the *impasse* would be to improve the propulsion unit at a faster rate than in the past. How this can be done without some new invention is uncertain, for the limitation on efficiency of jet engines is the same as has been discussed – namely high-temperature alloys.

Another item which he might have mentioned is maneuverability. *Stronger* alloys are only necessary to withstand higher stresses, and these largely come from violent turns. Is there enough air 20 miles up to shove the aircraft sharply right or left, up or down? Certainly a pilot would black out from large centrifugal forces. Even if quick turns can be made, cannot the principal stresses be carried by structural members inside the craft where they can be kept considerably cooler than the skin? Furthermore, how accurate have the aerodynamic theoreticians proven themselves to be? (Published curves showing Mach numbers versus skin temperature don't check very closely.) Finally, time of flight is another factor which vitiates any extrapolation of past developments. The fastest aircraft of the future will not fly at top speed very long; they will go straight to destination and maybe not return.

While there is no doubt that better and better materials are needed for aircraft, one wonders whether predictions based on requirements for fast, dog-fighting fighters are exactly realistic. Perhaps the ones we now have are good enough for a "small" war, or to screen the work horses, such as transports, freighters and refueling ships travelling at about 1000 miles per hr. Much faster bombers, but still far slower than Mach 5, can be looked upon as our best offense until the reliable intercontinental missile is ready. In either of these future weapons it would appear that metal having a high "Schapiro index" would be limited to the skin (even certain areas of the skin), and would need to work only a few minutes for if much of the skin were heated for considerable time a lot of the interior workings – electronic, hydraulic and pneumatic – would get so hot as to be quite unreliable.

Forming and Fabrication Methods

The trend toward stronger metals in airframes is also a trend toward harder metals, and indentation hardness is nearly always associated with difficulties in bending, forming, machining, drilling and other fabrication operations. It might almost be said that new dimensions have been added to all metallurgical requirements by aircraft engineers, and these requirements have in turn, by chain reactions, brought additional ones extending clear back into the mills themselves.

Airframes are made principally from sheet – or at least parts whose thickness is measured in thousandths. Weight is a prime consideration; every pound added to the structure means more pounds to the propulsion system to give necessary speed and more pounds of fuel and more pounds for a stronger structure to carry these heavier weights – a vicious spiral. The possible penalty of overweight due to tolerance of $-0.000 + 0.020$ in. on the aluminum wing skin only of a long-range bomber is 45 lb. Hence the closer and closer specifications for thickness for the heavier metals which become next to impossible to meet when cold rolling the harder, stronger alloys; no matter how husky the rolls and housings there is enough spring to produce

wide sheet a wee bit too thick at the center. Yet wide, long sheets are needed to reduce the number of joints; every joint means surplus weight. Here's a place where metal maker and aircraft manufacturer must reach a workable compromise.

Then there's flatness, the steelmaker's bug-a-boo. "Plate glass" flatness. That's hard enough in dead soft tin plate. Just try it in a naturally hard alloy, hardened even further by cold work and heat treatment and hence in a push-me pull-me balance of internal stress. But if the sheet isn't flat it gives plenty of trouble in fabrication and will probably end in a wavy part either worthless under compression stresses or – if it's a piece of exposed skin – causing unacceptable drag in fast flight, and if it isn't originally flat it probably won't conform to the required shape after it is pushed around in a forming machine.

Cutting of these hard materials was considered by one panel under leadership of Manuel C. Sanz, chief of materials research for North American's Missile Development Division at Downey. High hardnesses make machining so difficult that sometimes it's the tool that is wasted away almost as fast as the workpiece. However, teams of metallurgists, physicists, engineers and chemists have attacked this problem using vibrations at ultrasonic speed as well as by beefing up the more conventional or older tools. We now find ceramics (aluminum oxide) used as real cutting tools, not exclusively as tiny cutters in grinding wheels, but really to hog off metals.

Electrical energy is directly assisting in several ways. One of these is by spark discharge through a cheap tool of definite shape, thus cutting a depression or hole in the workpiece.* Another uses electrolytically controlled corrosion.

Then, too, chemical removal of metals is now used – this without the help of any electrical current.† While this "chem-milling" is really a very deep and uniform etch, ingenious use of chemical reaction between the metal and the bath is utilized. Those portions of a sheet which are to be untouched are screened off by a readily detachable mask of thin plastic. Fillets are automatically produced at the edges of such masks. "Chem-milling" is done on parts already formed; selected areas on such aluminum sheet 0.050 in. thick can be cut to 0.035 in. $\pm$ 0.002 with a surface roughness on the etched areas of 40 to 90 rms. (considerably smoother than the usual requirement of 125 rms. for aerodynamic surfaces).

Another panel headed by G. A. Moudry, technical director of Harvey Machine Co. of Torrance, discussed special forming techniques. This was almost a smorgasbord, and included the impact extrusion of aluminum and the drawing of zirconium tubing. The latter metal, almost a curiosity-shop item but a very few years back, is of extreme importance for corrosion resisting casings of fuel elements in atomic reactors, particularly the pressurized water-cooled type so successful in the submarine Nautilus. Within a short span of about a decade the production and fabrication of zirconium has become well understood. It is now made in ingots and billets of substantial size. Extrusions are produced with the help of thin copper casings which serve as lubricants, together with nonmetallic coatings of more or less conventional nature. In the handling of zirconium nothing can be done which will interfere with its spectroscopic cleanliness, as indeed is true of all materials forming a reactor core.

The "impact" extrusion described by Ray Quadt, vice-president of Hunter Douglas Aluminum Corp. of Riverside, is really misnamed, having little relationship to the smacking-out of a tooth-paste tube from a soft metal tablet. It is rather like back extrusion for cold forming an artillery shell. Speeds are not at all high. Notable rather is the quality of exterior finish, the concentricity of tubular forms, and the straightness of long aluminum rocket bodies. Furthermore, by proper choice of rams, dies and back-up tools a complex design can be formed – having, say, interior ribs on a thin wall at one end and a thick wall at the other, the two separated by a partially closed diaphragm. Such a shape would be very difficult and expensive to make by other means.

Use of Explosives – Among the newer methods of fabrication of airframe structural components is explosive forming. This is well named – it is just that. Sheet metal is forced into female open dies with incredible speed, in fact, by the shock wave of an explosion. The time required is measured in micro-seconds. Action is so fast that the sheet bangs up against the die contours before the metal has time to break! Hard,

*See "Machining Hard and Brittle Materials", by R. C. Hall, *Metal Progress*, August 1956, p. 78. Also "Russians Discover Spark Cutting", *Metal Progress*, January 1957, p. 121.

†The inventor of this process and chairman of the meeting, Manuel C. Sanz, has described the process in an article entitled "Skin Milling by Chemical Solution", in *Metal Progress* for October 1954.

"nonductile" metal is being successfully formed in this manner. Elongations are far beyond the normally expressed ductility figures – 100% elongation in metal with 20% tensile elongation has been produced with no sign of fracture.

There seem to be indications, too, that this method can be reduced in cost to compete with other more complicated operations on fully hardened alloys. At the opposite end of the hardness spectrum, annealed metals lose little if any of their ductility, having no indication of work hardening after being formed around sharp radii.

Size of part can be fairly large. A small area can be blown into an appropriate die with a shaped charge placed near by. Large pieces are sealed to the die around the edges, the explosive placed some distance above the sheet, the whole arrangement immersed in water, and the shock wave is carried to the expanse of metal through the fluid.

An explosive forming department should have little trouble in recruiting employees for a continuous Fourth of July!

Heat Resisting Materials

One of the cooperating societies, the Mining Engineers (short for American Institute of Mining, Metallurgical and Petroleum Engineers–Metals Branch) staged a well-attended meeting on Ultra High-Temperature Materials. Alan Levy of Marquardt Aircraft Co. led off with a review of the general situation regarding "elevated" temperatures. The available metals range from magnesium and aluminum alloys, retaining a considerable portion of their room temperature strength up to 600 or 800° F., through alloy steel to 1200° F., titanium alloys from 500 to 1100° F., depending upon analysis, age hardenable stainless steel to 1100° F., high-temperature alloys to 2100° F. and molybdenum alloys from 1600 to 2500° F. Their properties as used by designing engineers were given by Mr. Levy in this new dimension of elevated temperatures.

With the stage thus set, certain details were filled in the upper-temperature areas in separate papers describing molybdenum, carbides and cermets, and graphite.

Molybdenum and titanium seem to be mutually helpful in the high-temperature field. For example, Harold Margolin pointed out in *Metal Progress* for February 1957 (p. 86) that 3% molybdenum in titanium (rather than the 1.5 to 2% in commercial alloys) notably increases the creep resistance, rupture time, and strength-weight ratio. Robert R. Freeman of Climax Molybdenum Co., New York City, emphasized in the meeting at Los Angeles that conversely, sheet molybdenum with 0.5% titanium has a useful range extended substantially into higher temperature.* Metal derived from arc-cast ingots made by Parke's process, possesses a high Young's modulus of 47,000,000 psi. at room temperature and 40,000,000 psi. at 1600° F. It is especially ductile at this temperature, figures for stress-relieved bars being 88,000 psi. tensile strength, 76,000 yield, 15% elongation and 70% reduction of area. As is well known, high-molybdenum alloys require coatings to protect them from catastrophic oxidation, and Mr. Freeman gave the good news that promising coatings now seem to be available either as metal cladding or plating.

According to John C. Redmond, vice-president of Kennametal of Latrobe, Pa., ceramics and cemented carbides may be considered almost as alloys. Their outstanding performance in cutting tools suggested their value here. The fact that they don't have too high a density (about 5.5) is further to their advantage for air-borne parts. They have good oxidation resistance and are usable to 2200° F. They also have the highest Young's modulus of the materials considered in this meeting – being of the order of 50 to 56 million psi.

Finally a discussion of graphite was presented by J. E. Hove, solid state physicist for Atomics International of Canoga Park. It is something of a stranger in structural applications; nevertheless it resists temperatures to 3000° F., and in many ways acts more like a metal than a ceramic. Its low specific gravity (2.25 compared with 2.70 for aluminum) and lubricating value even when very hot are further advantages. It has the interesting property of increasing strength and modulus as the temperature is raised, but it must be protected from oxygen.

Materials for Short Life

The last remark should have a qualification: Hot graphite must be protected from oxygen if it is to last very long. The skin of intercontinental missiles, for example, need not last very long. Most of the journey is far above the atmosphere; coming down on target they plummet at meteoric speed and if they can function

*See "Properties of Arc-Cast Molybdenum", by Norman L. Deuble, *Metal Progress*, July 1955, p. 105.

for a few of these last seconds they have served well. Here again, the *time* parameter in engineering design is of an entirely different order of magnitude than in industrial machinery.

Mr. Levy's extensive tabulations of tensile properties and stress-rupture tests mentioned above were derived by methods developed in past years to evaluate long-time service under severe conditions. As was pointed out several times at the recent Albuquerque Conference on Heat Tolerant Metals for Aerodynamic Applications, the available data on materials at high temperature stop just when they begin to get interesting! For example, missile designers want to know the properties beyond where they are useful in a turbine, clear up to within a hundred degrees of their melting point. Entirely new equipment is needed to heat the sample red hot and test it, all in a matter of seconds.

Such matters were considered at an ASM session held under Alan Levy's chairmanship, leading off with a paper on the strength and yield of metals as they vary during rapid heating — underscore "rapid". Consider, for example, a metal which has been hardened by cold work. We know that this effect is lost by an anneal at T°, where recrystallization occurs. However, we seldom think that recrystallization takes time — a shorter time, of course, as the annealing temperature rises above T°, but nevertheless the softening and weakening is a time-dependent phenomenon. Similar statements may be made about the crystalline rearrangements leading to age hardening and over aging.

Heating and testing at rapid rates emphasizes these facts. Yield strengths are very considerably higher than reported in the conventional "short-time high-temperature tests". There appears to be a similar lag in all mechanical properties of steels, aluminum and other alloys which are affected by tempering, cold working and aging. In such short-time tests, furthermore, the matter of oxidation resistance becomes secondary, and hence the fact that "Schapiro index" of low-alloy steels is better than the best aluminum alloy at 800° F. becomes interesting.

Two methods of rapid heating were described, namely, resistance to electrical currents and heating by fluids. A surge of low-voltage current carried by the test piece gives a more uniform distribution of heat across the section than induced alternating currents. Stresses imposed by high-speed testing and resulting strains can be registered by oscilloscope circuits and recorded photographically.

It is difficult to summarize the results other than to say that strength and modulus of elasticity decrease with increasing temperature and the same properties usually *increase* with increasing strain rate. John A. Van Echo of Battelle Memorial Institute, Columbus, Ohio, found some qualitative relationship between creep properties of structural sheet materials and their short-time tensile properties, although the meaning of "creep" at such high rates of testing becomes somewhat misty.

The second method of heating was described by T. C. McGill, senior metallurgist for Convair, Pomona, under this title: "The Fluid Analogy to Aerodynamic Heating — a Testing Method Used in Development of Elevated-Temperature Structural Criteria for Application to Guided Missiles". Two heating mediums have been used, ash and molten salt at 1000° F. Time to bring to heat may be as short as 10 sec. Tension is then applied and the yield stress is reached in 5 sec. more, as an example. In these units actual missile sections can be tested as well as material coupons.

Alloys for Future Airframes

This whole group of papers may be rounded out by a brief account of a meeting on Alloys for Future Airframes held by the Mining Engineers. It led off with an account of metallurgical problems in fabrication of high-temperature airframes by J. Fred Baisch, materials unit chief for Boeing Airplane Co., Seattle, Wash. It is readily admitted that all metals have some shortcomings. Either they don't have the strength desired at the high temperatures to be encountered, or engineers want greater stiffness, better creep resistance, or longer fatigue life. So the designing engineer passes these problems on to the metallurgical engineer and the search for an improved metal is on.

A tank to hold fuming nitric acid under pressure was one item cited to show the breadth of the demands now being made. Here the form was such that ductility as well as chemical resistance and strength were important properties. Creep and dimensional growth at final temperatures also had to be considered. In forming these tanks hot (at 1400 to 1600° F.) an attempt was made to use an aluminum paint, baked on, to reduce galling, but it was later found that a ceramic (?) lubricant served better. It was also found that oxygen contamination of metal just under the surface scale had to be pickled off. (*Continued on p. 245*)

Cold Work Improves Age Hardening Stainless

*By JOHN T. RICHARDS and ELLSWORTH M. SMITH**

Age hardenable stainless may require complex and precise heat treatments for optimum properties. When mill annealed strip is rolled to hard or half-hard temper it has fair formability and age hardens to higher strengths during a simple reheating. (Q23q, J27d, 3-18; SS)

*Mr. Richards is chief engineer and Mr. Smith is chief metallurgist for Penn Precision Products, Inc., Reading, Pa.

EXCELLENT PROPERTIES resulting from precipitation hardening have led to rapidly expanded uses of the alloy known as "Armco 17-7 PH", a precipitation hardening stainless steel containing 0.07% C, 17% Cr, 7% Ni, and 1.2% Al. Readily formable in the soft temper or solution annealed state prior to aging, it can then be heat treated to a high level of strengh and hardness.

These characteristics, combined with good resistance to corrosion, make this alloy ideally suited for a wide range of elastic and structural components. Outstanding strength in tension and compression over a temperature range from subzero to 800° F. means a better weight-strength ratio, especially at the high range of temperaure, than other materials now used for supersonic aircraft and missiles – that is to say, the strong aluminum alloys, the strong magnesium alloys, and the titanium alloys 92 Ti-8 Mn and 90 Ti-6 Al-4 V. Other uses include springs, diaphragms, electronics and instrument parts.

In an article by M. W. Marshall and his associates in *Metal Progress*, July 1956, the mechanical properties and processing techniques were presented for various heat treated conditions. Condition A as described by these authors represents the commercial anneal at 1950° F., really a solution treatment, to a soft temper and is the universal first step in all subsequent heat treatments. Condition A 1750 results after a reheat to 1750° F. Condition TH 1050 is reheated to 1400° F. and aged at 1050° F. Condition R 100 is reheated to 1950° F. and refrigerated 8 hr. at − 100° F., while Condition RH 950 has still another treatment – aging at 950° F. for 1 hr.

The article above mentioned describes fully the properties in these conditions, but it will be noted that they all depend on heat treatment, some of them rather complicated and costly. We have studied for some time the additional advantages due to cold work, and this article summarizes our findings. For many applications, the full formability of Condition A (commercial anneal) is not required; in fact, higher strengths and simplified heat treatments can be obtained through the use of cold rolled material.

The primarily austenitic structure of solution annealed material (soft) can be transformed to martensite (much harder) either through cold work or heat treatment; further hardening and strengthening results from precipitation of microscopic constituents upon heating at about 900° F.

Mill annealed sheet in Condition A must be heat treated (usually 90 min. at 1400° F.) to

Table I – Typical Mechanical Properties of Cold Rolled 17-7 PH Strip

	Cold Rolled		Subsequently Age Hardened	
	Condition 1/2C	Condition C	Condition 1/2C	Condition C
Tensile strength, psi.	180 to 200,000	210 to 235,000	235 to 260,000	275 to 315,000
Elongation in 2 in., %	8 to 11	1 to 2	0 to 2	0 to 2
Superficial hardness*				
30 N Scale	62 to 65	64 to 68	68 to 72	71 to 75
15 N Scale	81 to 84	83 to 86	85 to 88	87 to 90

*Superficial hardness applies for strip 0.010 in. thick and thicker.

bring about a martensitic transformation. Precipitation hardening occurs in such "conditioned metal" by subsequent heating (aging) at either 950 or 1050° F., depending upon the combination of final properties desired. Parts requiring some ductility or improved resistance to impact in the heat treated condition are usually aged at the higher temperature; strip so treated will have a tensile strength ranging from 180,000 to 200,000 psi. Condition RH 950 includes a cooling to − 100° F. and holding for 8 hr., followed by aging for 1 hr. at 950° F. By virtue of a more complete transformation to martensite, tensile strengths ranging from 225,000 up to 240,000 psi. can be attained.

We find that severely cold rolled 17-7 PH (Condition C) transforms to martensite during work hardening. Therefore, heat treatment to transform the structure is eliminated. Age hardening for 1 to 2 hr. at 900° F. produces tensile strengths higher than 240,000 psi.

Generally, strip is supplied by the mill in either Condition A or Condition C, and the customer fabricates the parts prior to heat treatment. If he uses Condition A material, both transformation and aging treatments are necessary; if he uses Condition C strip, only precipitation hardening (aging) is needed.

The present article reports only our investigations of rolled tempers (Condition C). The chief advantage of this condition is the elimination of the transformation heat treatment; parts requiring limited formability can be finished by a single aging operation.

Temper Selection

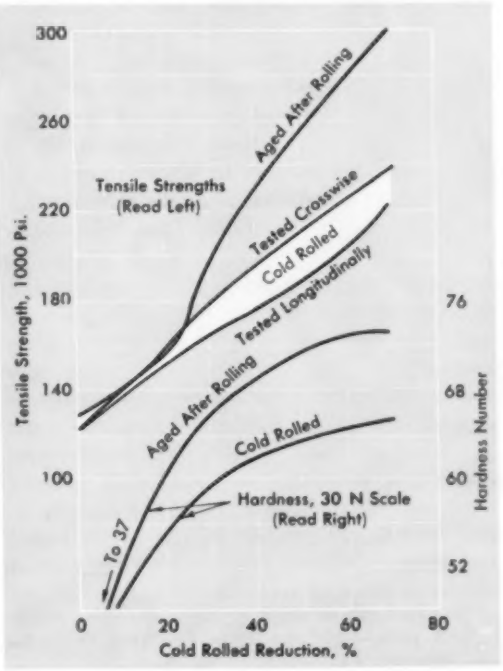
Although the cold rolled Condition C offers maximum strength and hardness after aging, it has a decreased amount of formability. Therefore, an intermediate temper seemed desirable. The requirements of this temper include *(a)* moderate formability, *(b)* ability to respond to aging, and *(c)* useful properties after aging.

The work hardening rate of 17-7 PH was compared with that of the ordinary 18-8's, Types 301 and 302. Tensile strengths at zero, moderate and heavy cold reduction are as follows:

	Annealed	30%	70%
17-7 PH	120,000	165,000	225,000
Type 301	115,000	165,000	270,000
Type 302	105,000	165,000	250,000

Although 17-7 PH is slightly stronger as annealed, its work hardening rate is less – so that at higher reductions it has a lower tensile strength than the other two varieties of stainless. This lower strain hardening rate would

Fig. 1 – Tensile Strength and Hardness of Cold Rolled 17-7 PH Strip, Tested Longitudinally After Various Amounts of Reduction. Hardening and strengthening by aging 75 min. at 900° F. is also shown, as also (in white area) the variation in strength to be expected due to directionality



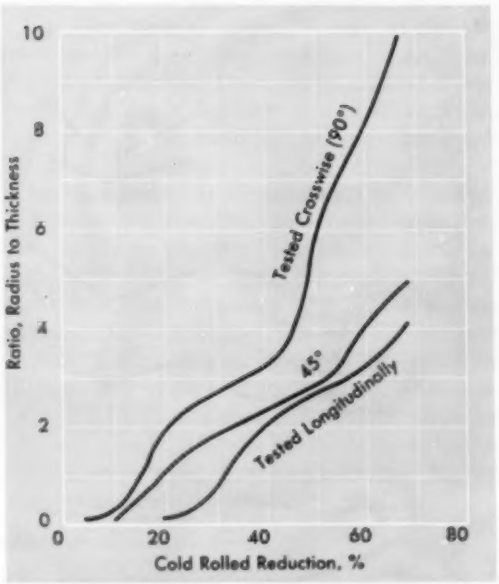


Fig. 2 – Relative Formability of 17-7 PH Strip Is Affected by Cold Rolling and Angle of Bend With Rolling Direction. Diagram applies to strip 0.020 to 0.050 in. thick

indicate that for a given cold rolled reduction, forming characteristics of 17-7 PH would be slightly better than Types 301 and 302.

To determine the minimum amount of reduction by cold rolling to induce hardening by a subsequent aging, specimens were rolled varying amounts and then aged 75 min. at 900° F. As shown in Fig. 1, cold reduction of more than 20% is required to strengthen the metal further by heat treatment. (The slight improvement in hardness shown for slightly cold rolled strip may be a function of stress-relief rather than age hardening.) With increased reductions, the improvement resulting from heat treatment becomes increasingly greater for both tensile strength and hardness. Figure 1 indicates that at least 30% reduction is required to produce significant aging. At the same time, the aged tensile strengths after 50% or more cold rolling and aging exceed the maximum (about 240,000 psi.) obtained in Condition A strip following any of the heat treatments studied by Mr. Marshall and his associates.

Relative formability was determined by cold bending to a 90° angle around a radius block. Suitable specimens of cold rolled strip of various reductions were cut at 0°, 45° and 90° to the rolling direction. A specimen of poor formability will crack when formed over a sharp radius. This tendency decreases as the punch radius is increased until only "orange peel" can be seen on the outside of the bend; further increases in punch radius will lessen the amount. After bending, specimens were inspected under a seven-power glass, and the minimum punch radius without forming orange peel was used as the end point.

Relative formability is expressed as the ratio of punch radius to stock thickness. Therefore, a value of 2 means that the minimum safe punch radius for forming a 90° bend without producing orange peel would be twice the stock thickness. This ratio for stainless alloys varies with thickness, so that thicker stock (other conditions being equal) is less formable than thinner. Typical results for 17-7 PH strip 0.020 to 0.050 in. thick are shown in Fig. 2 for three directions, tested longitudinally (0°), tested at 45°, and crosswise (90°).

From these preliminary investigations, several factors were noted that should influence the

Table II – Relative Formability* of 17-7 PH

Thickness, In.	Angle With Rolling Direction					
	Condition 1/2 C			Condition C		
	0°	45°	90°	0°	45°	90°
0.005 to 0.008	0.4	0.5	2.0	1.0	1.0	7.1
0.008 to 0.012	0.5	0.6	2.5	2.0	2.1	7.6
0.012 to 0.016	0.6	1.0	4.0	3.0	3.2	8.2
0.016 to 0.020	1.0	1.5	4.3	4.0	4.4	8.8
0.020 to 0.030	2.5	3.0	4.8	5.0	6.0	9.6

Table III – Relative Formabilities of Three Stainless Steels

Alloy	Temper	Tensile Strength	Relative Formability*		
			Angle With Rolling Direction		
			0°	45°	90°
17-7 PH	1/2C	182,000	2.2	2.2	3.2
301	3/4 hard	176,000	1.0	4.3	4.0
	Hard	199,000	2.3	5.3	5.3
302	3/4 hard	175,000	0.9	0.7	1.8
	Hard	195,000	2.1	3.2	4.0
17-7 PH	C	216,000	3.5	4.4	8.7
301	Extra hard	226,000	4.5	4.5	6.7
302	Extra hard	208,000	4.0	4.0	6.0

*Ratio of punch radius to stock thickness for strip 0.015 to 0.028 in. thick.

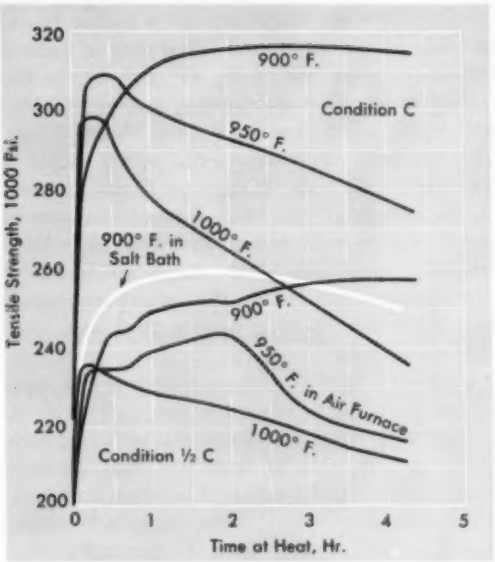


Fig. 3 – Influence of Cold Rolling, Aging Time and Aging Temperature on Tensile Strength of 17-7 PH Strip

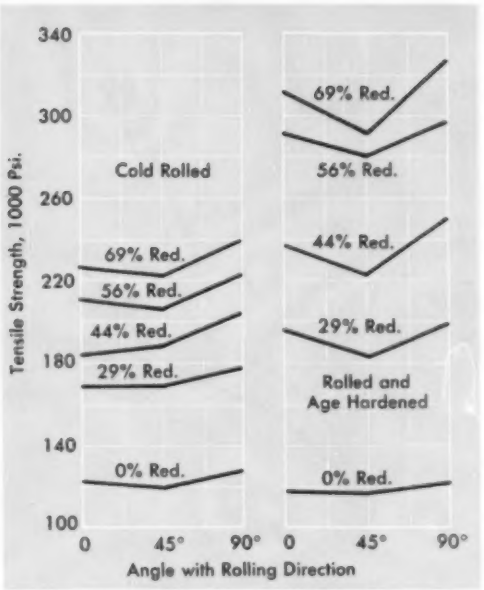


Fig. 4 – Directional Characteristics of 17-7 PH Strip Rolled to Various Reductions (Left) and Then Heat Treated 75 Min. at 900° F. (Right)

specifications for an intermediate temper. First, ductility (as measured by elongation as well as relative formability in the bend test) dropped substantially when strip was cold rolled to strengths exceeding 200,000 psi.; nevertheless this figure must be approached if the material can be hardened by heat treatment to strengths above that produced by heat treating the steel in Condition A (mill annealed).

To meet these conditions, the tentative specifications shown in Table I were established. If the initial tensile strength (Condition ½ C or half-hard, cold reduced 40 to 50%) falls within the range of 180,000 to 200,000 psi. tensile strengths of approximately 245,000 psi. can be attained through precipitation hardening. The presence of at least 8% elongation prior to aging guarantees moderate formability.

Typical mechanical properties for full hard Condition C material (cold rolled 60% or more) are also included in Table I. Consequently, if formability is not a problem, tensile strengths of at least 275,000 psi. can be obtained after aging. For relatively thin strip, strengths above 300,000 psi. are easily reached.

Formability of 17-7 PH strip is shown in Table II. The effect of thickness upon the forming ratio is apparent. For both Conditions ½ C and C, formability in the 90° direction is substantially lower than that between 0° and 45°. Therefore, forming should be carried out preferably at 0 to 45° to the direction of rolling, since bending across the strip (90°) will prove more difficult.

Table III affords a comparison of the relative formability of 17-7 PH with Types 301 and 302. In the ½ C temper, formability of 17-7 PH seems to fall between that of ¾-hard and full-hard Types 301 and 302. The formability of Condition C is similar to that of extra hard 301 or 302, although greater directionality is observed. Although 17-7 PH strip in Condition ½ C offers interesting possibilities, for maximum performance it is generally desirable to select the highest temper that will withstand the forming requirements.

Heat Treatment

Although aging tests were mainly carried out for 75 min. at 900° F., other times and temperatures were also investigated. Figure 3 shows the influence of time and temperature upon the tensile strength of strip in Condition ½ C and C. It is apparent that the 75 min. at 900° F. is not enough for Condition ½ C strip; higher tensile strength results from longer heat treating times. For best results, ½ C material should be aged 2 to 3 hr. at 900° F.; 950 and 1000° F. cause over-aging.

For Condition C strip, 75 min. at 900° F. produces excellent properties, but 2 to 3 hr. gives the maximum. Overaging occurs relatively rapidly at either 950 or 1000° F. Aged Condition C material is substantially stronger than aged Condition ½ C strip.

Another factor to consider is the influence of heating rate upon the time required to produce maximum strength. The white line in Fig. 3 shows results after aging in a salt bath; the black lines are for pieces heat treated in an air furnace. The higher rate of heat transfer associated with salts baths produces maximum strength in 2 hr. at 900° F.; however, in the air furnace 3 to 4 hr. is needed to obtain the same level of strength. For muffle furnaces or bright atmosphere heating, even longer times or higher temperatures will be needed.

Directionality

The effect of cold rolling upon directional characteristics of stainless strip is well known. The white area in Fig. 1 illustrates this for the new alloy 17-7 PH. As anticipated, tensile specimens cut 90° to the direction of rolling were found to give somewhat higher tensile values than 0 to 45° specimens. (Little or no difference was noted between the two latter, as shown at the left of Fig. 4.) Directional characteristics were found to increase with increased reductions in cold rolling.

The directionality of age hardened material was also studied and the results are shown at the right of Fig. 4. Directionality is increased by heat treatment, since the drop of strength in the 45° direction becomes more pronounced.

Conclusions

For those applications not requiring severe forming, cold rolled tempers offer advantages over mill annealed Condition A. The transformation heat treatment becomes unnecessary. At the same time, both Conditions ½ C and C yield substantially higher tensile strength and hardness than Condition A material. For many springs and related applications, the ½ C temper offers excellent strength combined with moderate formability. Where formability is not a factor, Condition C material should be used in order to obtain highest strength and hardness. Compared with other hardenable grades of stainless, the heat treatment of rolled 17-7 PH is relatively simple and is not critical with respect to time and temperature.

Light Metallurgy . . .

A Glossary for Research Reports

By C. D. GRAHAM, JR.

Alloy Studies Research,
Research Laboratory, General Electric Co.,
Schenectady, N.Y.

Common words and phrases used in the literature of metallurgy and their real meanings.

INTRODUCTION

It has long been known that . . . I haven't bothered to look up the original reference.

. . . of great theoretical and practical importance . . . interesting to me.

While it has not been possible to provide definite answers to these questions . . . The experiments didn't work out, but I figured I could at least get a publication out of it.

EXPERIMENTAL PROCEDURE

The W-Pb system was chosen as especially suitable to show the predicted behavior . . . The fellow in the next lab had some already made up.

High-purity . . . Very high purity . . . Extremely high purity . . . Super-purity . . . Spectroscopically pure . . . Composition unknown except for the exaggerated claims of the supplier.

A fiducial reference line . . . A scratch.

Three of the samples were chosen for detailed study . . . The results on the others didn't make sense and were ignored.

. . . accidentally strained during mounting . . . dropped on the floor.

. . . handled with extreme care throughout the experiments . . . not dropped on the floor.

. . . given a homogenizing anneal . . . oxidized.

RESULTS

Typical results are shown . . . The best results are shown.

Although some detail has been lost in reproduction, it is clear from the original micrograph that . . . It is impossible to tell from the micrograph.

Presumably at longer times . . . I didn't take time to find out.

The agreement with the predicted curve is
excellent . . . fair.
good . . . poor.
satisfactory . . . doubtful.
fair . . . imaginary.

. . . as good as could be expected considering the approximations made in the analysis . . . non-existent.

These results will be reported at a later date . . . I might possibly get around to this sometime.

The most reliable values are those of Jones . . . He was a student of mine.

DISCUSSION

It is suggested that . . . It is believed that . . . It may be that . . . I think.

It is generally believed that . . . A couple of other guys think so too.

It might be argued that . . . I have such a good answer to this objection that I shall now raise it.

It is clear that much additional work will be required before a complete understanding . . . I don't understand it.

Unfortunately, a quantitative theory to account for these effects has not been formulated . . . Neither does anybody else.

Correct within an order of magnitude . . . wrong.

It is to be hoped that this work will stimulate further work in the field . . . This paper isn't very good, but neither are any of the others in this miserable subject.

ACKNOWLEDGEMENTS

Thanks are due to Joe Glotz for assistance with the experiments and to John Doe for valuable discussions . . . Glotz did the work and Doe explained what it meant.

Iron Stand You!

Myron Weiss, a good friend of *Metal Progress*, sends this clipping from a recent letter from his class of 1925. It is said to have been written to Harvard's President Pusey toward the end of the depression in the 1930's.

HALOGENS:

As I am an aluminum of two colleges besides Harvard, and cannot, with my bismuth in its present state, pay antimony to all three, I hope you will not think me a cadmium if I do not cesium this opportunity of making a donation. So far this year I have metal current expenses, but in these troubled times when the future holds in store we know not phosphorus, I could not make a contribution without boron from the bank. It would nickle savings. A manganese spend his dollars these days; a tin spot is gone in no time. One is lead to feel he is pouring them down the zinc. Much better to sodium up in a stocking.

So don't be silicon not make any contribution this year unless a bromine helps me out.

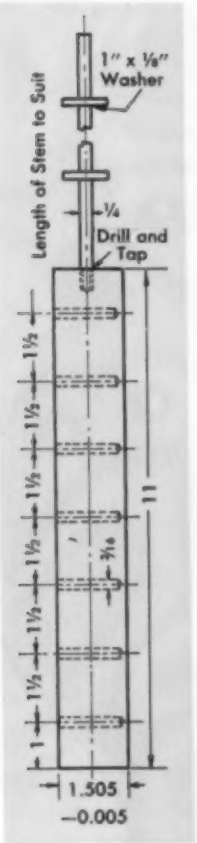


Fig. 1 – Test Specimen, With Thermocouple Wells and Supporting Stem

Hardenability Test for Deep Hardening Steels

*By CARL M. CARMAN, DOMINICK F. ARMIENTO and HAROLD MARKUS**

A 1.5 × 11-in. test piece is austenitized uniformly in a tube furnace then lowered 3 in. and the protruding end cooled with a jet of water while the furnace is being cooled at a rate corresponding to the 3-in. position on the test piece. (J5, I-4; AY)

STEELS USED in the manufacture of very large sections must possess deep hardening properties. In the hardenability testing of such steels, the standard 1-in. diameter by 4-in. long Jominy test specimen hardens along practically its full length and gives no information concerning the limiting hardenability of the steel. A useful hardenability test must closely approximate the actual cooling during quenching of a heat treated part, should be accurately controlled, and should be amenable to mathematical analysis.

The simplest type of test would be to use an oversized Jominy specimen 3 in. diameter and 12 in. long. In end quenching such a specimen, however, it has been found that air cooling was predominant at positions greater than 2 in. from the quenched end.

Wm. Wilson, Jr. has described such a test in "End-Quench Bar for Deep Hardening Steels" in *Transactions*, ASM, Vol. 43, p. 454, which may be used for these steels but has some disadvantages. Wilson's test specimen is 1½ in. diameter by 11 in. long. It is austenitized and end

*Messrs. Carman and Armiento are metallurgists and Mr. Markus is director of metallurgy, Research Laboratory, Pitman-Dunn Laboratories, Frankford Arsenal, Philadelphia.

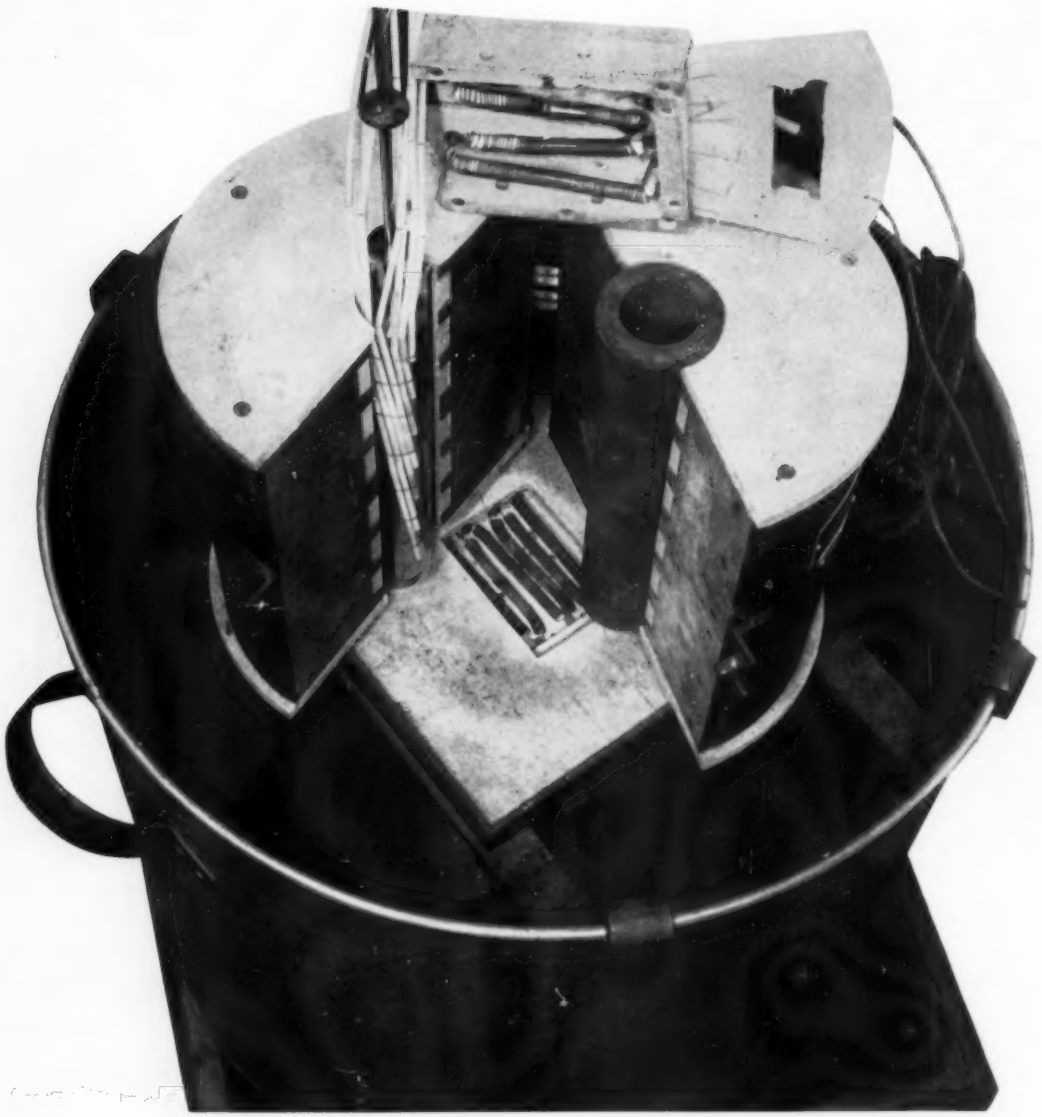


Fig. 2 – Heating Furnace, in Open Position, Resting on Quench Tank. Top heater is tilted on one side. Specimen with thermocouples is placed inside heavy tube in the center of the furnace. After austenitizing, specimen and tube are lowered 3 in. and end quenched

quenched in a tube furnace which has cooling coils in the furnace walls. By a combination of end quenching, water cooling of the furnace walls and control of the furnace heating elements, he reproduced the average cooling curves observed in commercial oil quenching. A major disadvantage other than the complexity of the furnace is that cooling curves must be determined on each test as it is run. By modifying the Wilson equipment and procedure, we find we can make consistent hardenability tests for the deep hardening steels using a simpler technique based on the theoretical cooling of the oversized Jominy specimen.

The specimen is a 1½-in. diameter bar 11 in. long, having seven thermocouple wells along its length (Fig. 1) and a supporting stem. The furnace is a three-zone vertical tube furnace made by the Hevi-Duty Electric Co. Power to each zone is controlled independently by manually operated variacs.

Details of the specimen, furnace and quench-

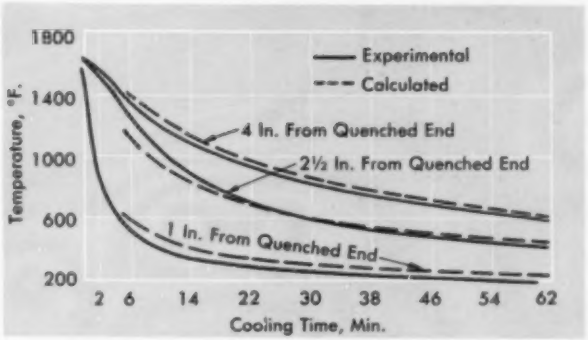


Fig. 3 – Comparison of Calculated and Experimental Cooling Curves for Test Having 3 In. of Specimen Extended, With Equalizer Tube Surrounding the Specimen During Quenching

ing tank are shown in Fig. 2. The two small end heaters and the heavy stainless steel equalizer tube, in conjunction with independent power control in each zone of the furnace, permit a uniform temperature along the specimen for austenitizing.

In conducting the test, the specimen is heated to the proper austenitizing temperature and soaked for 1 hr. Power to the end heaters is then turned off and the bottom end heater withdrawn. The specimen is lowered 3 in. through the furnace and end quenched with a standard Jominy stream. The equalizer tube must also be lowered to surround the specimen during quenching, except for ⅛ to ¼ in. at the bottom end. In the meantime, the furnace is cooled by the program controller in a cycle that corresponds to the water quenching effect at the 3-in. position of a 12-in. Jominy specimen. Cooling at the seven positions along the bar is recorded by a multipoint instrument.

Typical cooling curves are shown in Fig. 3. For routine work a thermocouple can regulate each zone rather than the seven couples used for the experimental work.

Two parallel flats 0.030 in. deep are ground along the specimen and Rockwell C-scale hardness readings are taken on these flats at specified distances from the quenched end.

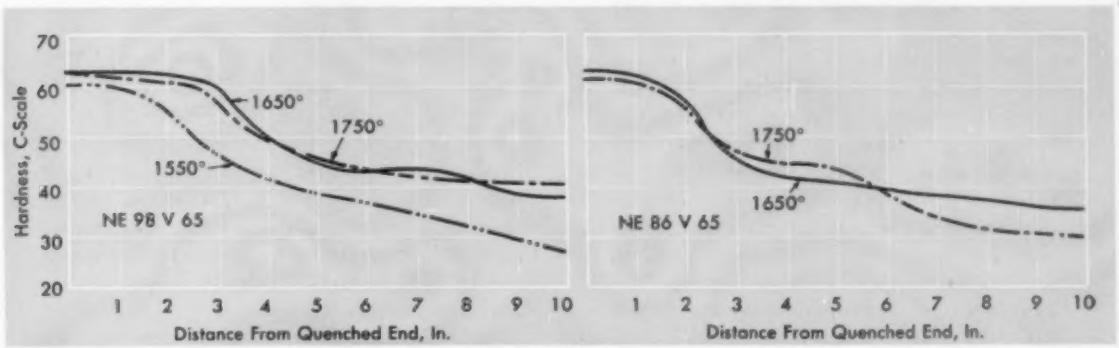
Utility – A hardenability test, to be useful, must be able to predict the effects of variations of heat treating practice on the response to a hardening operation. One of the more common variations is to change the austenitizing temperature. As an example this was done for two grades of steel – NE 98 V 65 (Heat No. 1) and NE 86 V 65, whose analyses are:

	NE 98 V 65	NE 86 V 65
Carbon	0.68%	0.60%
Manganese	0.95	0.87
Silicon	0.21	0.30
Chromium	0.95	1.22
Nickel	1.09	0.52
Molybdenum	0.31	0.21
Vanadium	0.09	0.08

The distance to Rockwell C-58 increased as the austenitizing temperature of NE 98 V 65 steel was raised from 1550° F. to 1650° F. However, the hardenability was not further affected by raising the austenitizing temperature to 1750° F. (Fig. 4, left). The hardenability of NE 86 V 65 was not affected by raising the austenitizing temperature from 1650° F. to 1750° F. (Fig. 4, right). These curves check the observations made when heat treating 4-in. rounds of the same steels. From these data it appears that this test has sufficient sensitivity.

An additional requirement for a hardenability

Fig. 4 – Test Shows That Hardenability of One Deep Hardening Steel Depends on Austenitizing Temperature, but not of Another



test is that it should be reproducible. To determine if this test is reproducible 13 specimens of NE 98 V 65 steel (Heat No. 2) were austenitized at 1650° F. and quenched. This steel was of commercial manufacture, received as hot rolled annealed bars, and purchased under Specification QQ-S-624 with special composition limits.

The results of the tests on this one heat are as shown in Fig. 5. The average distance to C-58 for the 13 specimens is 2.102 in. with a standard deviation of 0.151 in. and a standard error for the mean of 0.0418 in. From this it may be inferred that the 95% confidence interval for the mean is 2.102 ± 0.091 in.

Hardenability of four heats of NE 98 V 65 has been studied and the results are in accord with production heat treating experience. The hardenability variation within these samples is not a function of variation in chemical composition and must be attributed to other factors. Isothermal transformation studies of Heats 2 and 4 showed that Heat 4 has a longer incubation period and slower reaction rate than Heat 2. Marquenched rounds of Heat 2, 3 in. in diameter, showed 2 to 3% bainite in the center, whereas 5-in. rounds of Heat 4 similarly treated showed none. Difficultly soluble carbides in Heat 2 are undoubtedly responsible for the lower hardenability of this steel, although it is certainly not the only factor.

Because of the recent interest shown in the possibility of substituting the higher carbon grades of the A.I.S.I. 4100 series for the higher alloy NE 98 V 65 steel, hardenability tests as described above were conducted on commercial heats of 4150, 4160, and 4170 steel austenitized at 1600° F., with results as shown in Fig. 6. These steels evidently do not have hardenability equivalent to NE 98 V 65. The increase in carbon content from 0.52 in the 4150 to 0.68% in the 4170 is quite effective in increasing the hardenability. Other alloying elements were within a narrow range: 0.76 to 0.83 Mn, 0.23 to 0.30 Si, 0.97 to 1.01 Cr, 0.13 to 0.24 Ni and 0.20 to 0.23 Mo.

The hardness increase observed at the 4 to 5-in. position along these specimens is not at all unusual. It has been described previously by Gordon T. Williams in the paper entitled

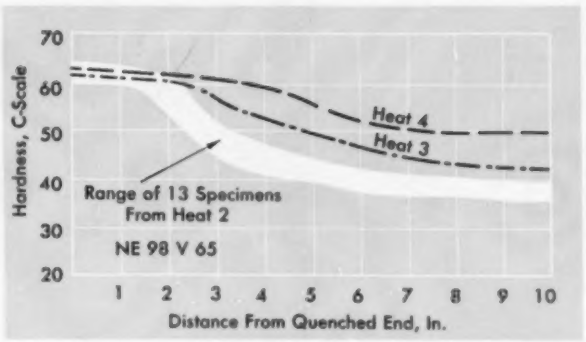


Fig. 5 – Scatter Band of 13 Test Pieces From Heat 2, and Hardenability Curves for Single Tests From Heats 3 and 4, NE 98 V 65 Steel, Austenitized at 1650° F.

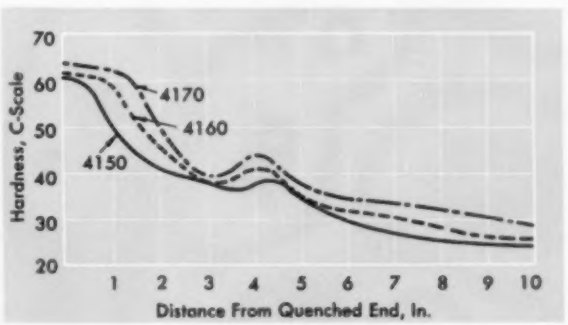


Fig. 6 – End Quench Hardenability of Three Heats of A.I.S.I. 4100 Series, as Made by the Proposed Test Method

"Hardenability Variations in Alloy Steels – Some Investigations With the End Quench Test", *Transactions*, ASM, Vol. 28, 1949, p. 157 to 185. He assigns this peculiarity to "the change in structure from an intermediate constituent (pseudomartensite) to pearlite".

Conclusion – The standardized end quench test is not able to discriminate between many of the deep hardening steels, yet it is quite desirable to select commercial steels with minimum alloy content, and yet be able to heat treat them effectively in large masses. This article describes a method of test, which while not as simple as the Jominy test for the engineering steels made into parts of moderate size, has been quite useful in studying steels for more massive items. It is able to distinguish between commercial heats of the same grade having minor variations in hardenability, which have not yet been satisfactorily related to the steel's composition or its past history, and hence are unpredictable.

Sigma Formation in Commercial Ni-Cr-Fe Alloys

By FRANCIS B. FOLEY
*and VSEVELOD N. KRIVOBOK**

Formation of sigma phase in high Cr-Ni alloys of iron is usually blamed for embrittlement of the alloys after long heating, but there is reason to believe that some more subtle phenomenon is also a contributing factor. (N8, Q6n, 3-18; SS)

MUCH OF THE available knowledge concerning the relationship of nickel and chromium in the formation of sigma phase in iron-base alloys and its effect on the mechanical properties has been derived from pure materials or alloys of random composition. An exception is a study by A. M. Talbot and D. E. Furman† who determined, among other properties, the impact values of Fe-Ni-Cr alloys of commercial compositions. Recently many additional experimental values have been secured. We have now combined these data and constructed three-dimensional figures to show graphically how nickel and chromium *mutually* influence the amount of sigma phase and consequently the toughness of wrought commercial type alloys after exposures of up to 3000 hr. to temperatures at which sigma is likely to form. The importance of the time variable in evaluating the presence (or absence) of sigma phase, and therefore in establishing the phase boundaries, is quite obvious.

It should be remembered that all the alloys on which the present article is based contained approximately 0.05% C, 1.9% Mn, and 0.7% Si. (The importance of silicon content is discussed later.) Bars were hot rolled to ¾ in. diameter from 2-in. square ingots and then cold rolled to ½-in. squares. During cold rolling the bars were given an intermediate anneal; the final cold reduction was 23%. Half of each heat was retained in this cold rolled condition and the other half was quench-annealed in the range 1900 to 1975° F. to approximately the same grain size in each heat. Specimens in these two initial conditions were heated to 1200, 1475 and 1650° F. for periods of 100, 500, 1000 and 3000 hr., machined to standard keyhole Charpy impact specimens and tested at room temperature. Microscopically detectable sigma was estimated after the 3000-hr. exposures only.

Effect of Composition

The percentage of sigma phase so identified is shown diagramatically in Fig. 1 and 2. In constructing the diagrams, the temptation to extrapolate has been resisted, as far as possible, and only the results of actual examinations, as indicated by open circles and figures alongside, were used.

A comparison of Fig. 1, representing the quench-annealed alloys, with Fig. 2, representing the cold worked ones, shows that cold working increases the amount of sigma present and extends the area of composition in which it develops, especially after the 1200° F. exposure. The diagrams for the higher temperatures are

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†"Sigma Formation and Its Effect on the Impact Properties of Iron-Nickel-Chromium Alloys", by A. M. Talbot and D. E. Furman, *Transactions*, American Society for Metals, Vol. 45, 1953, p. 429.

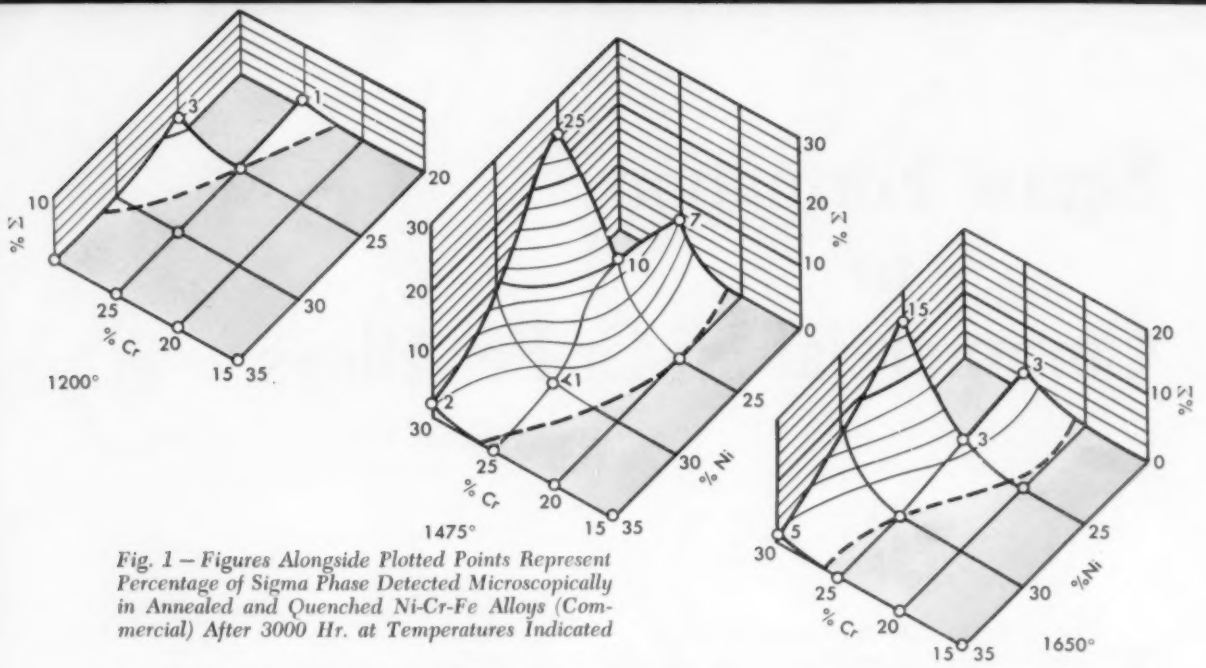


Fig. 1 – Figures Alongside Plotted Points Represent Percentage of Sigma Phase Detected Microscopically in Annealed and Quenched Ni-Cr-Fe Alloys (Commercial) After 3000 Hr. at Temperatures Indicated

much more alike, with a somewhat larger amount of sigma appearing in the cold worked specimens (particularly the cold worked 30 Cr, 35 Ni alloy) than in the corresponding materials of Fig. 1.

The limiting values of chromium and nickel for sigma formation in these iron-base alloys are indicated by the broken line bounding the tinted area at the base of the diagrams. Under the conditions of this investigation these values are as shown in the table at top of p. 84.

Charpy Impact Values – While the sigma phase was estimated only after the 3000-hr. exposures, Charpy impact values were determined after both the 3000-hr. and the 100-hr. exposures. Both sets of Charpy values are shown diagramatically in Fig. 3 and 4, by solid and broken lines respectively. For clarity of presentation it has been necessary to turn these models 180° with respect to those of Fig. 1 and 2; the 15-35 Cr-Ni alloy was in the foreground, and in Fig. 3 and 4 is now at the farthest point in the

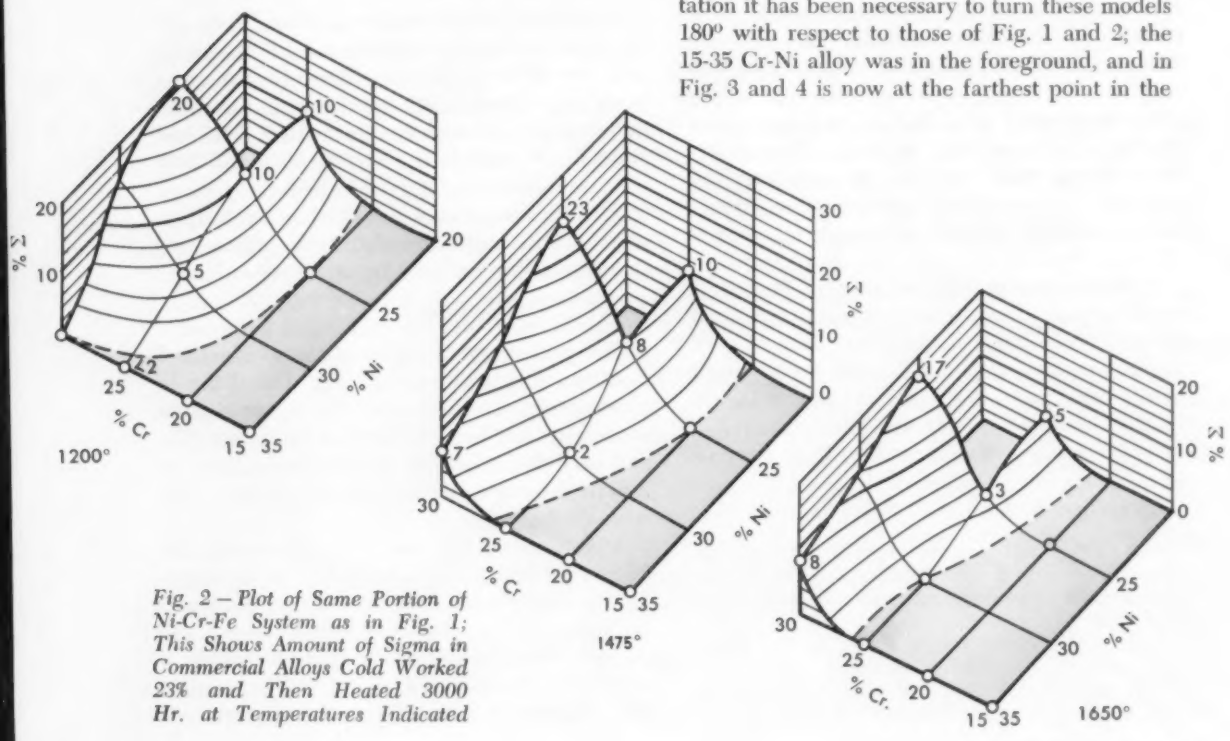


Fig. 2 – Plot of Same Portion of Ni-Cr-Fe System as in Fig. 1; This Shows Amount of Sigma in Commercial Alloys Cold Worked 23% and Then Heated 3000 Hr. at Temperatures Indicated

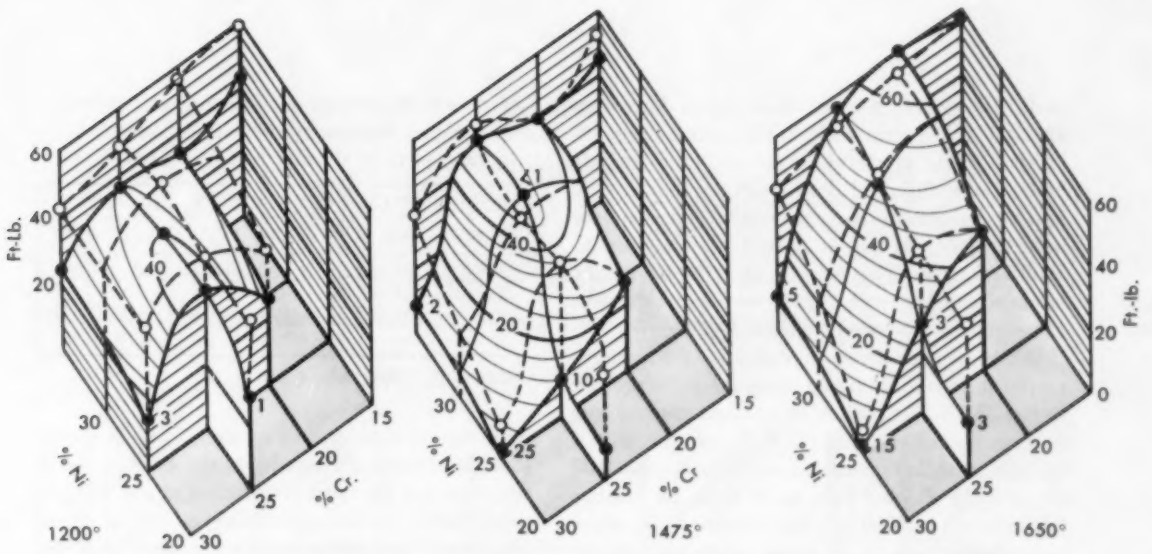
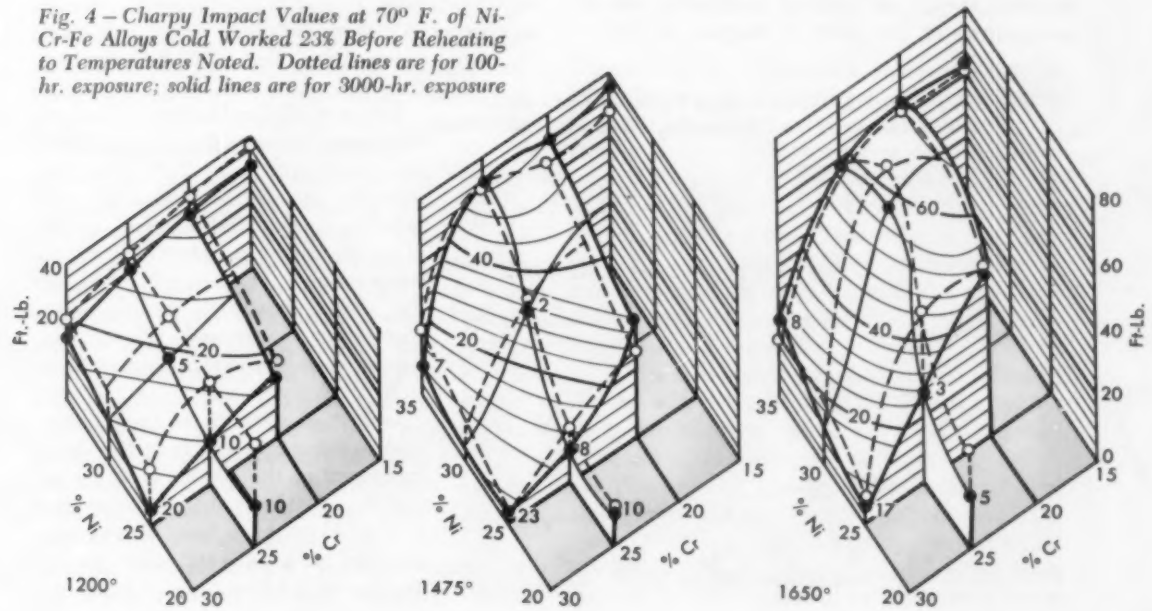


Fig. 3 — Charpy Impact Values for Annealed Commercial Ni-Cr-Fe Alloys After 100-Hr. Exposure (Dotted Lines) and 3000-Hr. Exposure (Solid Lines) to 1200, 1475 and 1650° F. Figures alongside plotted points indicate amount of sigma phase in microstructure after 3000-hr. exposure

diagrams. Where sigma phase was found microscopically after the 3000-hr. exposures the estimated amount is indicated

Effect of Heating to 1200° F. — After heating the annealed alloys to 1200° F. detectable amounts of sigma were present in those alloys having the combination of lowest nickel and highest chromium. These impact values did not fall below 15 ft-lb., as shown in Fig. 3. The range was 17 to 43 ft-lb. after 3000 hr. at temperature. Prior to reheating, the values for the annealed specimens fell within the range of 65 to 79 ft-lb., and the cold worked ones between 32 and 48 ft-lb. It is quite apparent from the 1200° F. diagram in Fig. 3 that the impact values of all the annealed alloys (65 to 79 ft-lb.) were markedly reduced by the 100-hr. heat treatment (dotted lines) and still further by the 3000-hr. exposure, even when no sigma has been detected microscopically. This would seem to indicate that a noteworthy loss of impact resistance in the quench-annealed alloys resulted from

Fig. 4 — Charpy Impact Values at 70° F. of Ni-Cr-Fe Alloys Cold Worked 23% Before Reheating to Temperatures Noted. Dotted lines are for 100-hr. exposure; solid lines are for 3000-hr. exposure



embrittling factors other than sigma formation at 1200° F. – presumably from carbide precipitation. It is doubtful, however, that carbide embrittlement could *continue* to reduce the impact values to such a marked degree for holding times in excess of 100 hr. (and up to 3000 hr.), since long heating at 1200° F. usually tends to restore, rather than to impair, the loss of toughness produced by short heating.

While it may seem doubtful that submicroscopic or nonvisible sigma phase could be present in the 35-15 Ni-Cr alloy to account for the loss in impact value from 65 ft-lb. in the initial quench-annealed condition to 58 ft-lb. after 100 hr. at 1200° F. and then to 43 ft-lb. by further exposure up to 3000 hr., the conclusion is rather inescapable that it, or some other embrittling phase, is in fact present. The amounts are evidently too small for detection microscopically or even by X-ray diffraction, yet are sufficient to lower the impact resistance to a perceptible, yet harmless, degree. Four days (96 hr.) at 1200° F. should be sufficient for any embrittling effect of carbide precipitation to reach its maximum effect, and one hardly looks for this to continue for four months (3000 hr.). Sigma phase, on the other hand, is notoriously sluggish in forming in annealed material at so low a temperature as this.

Cold working alone reduced the initial impact values of the annealed metal from the 65 to 79 ft-lb. range to 32 to 48 ft-lb. The 100-hr. heating at 1200° F. reduced these values further to 16 to 38 ft-lb. and 3000 hr. to 5 to 31 ft-lb. A comparison of the 1200° F. diagram of Fig. 4 with the other diagrams of Fig. 3 and 4 shows that this temperature reduces the Charpy value the most – is the most embrittling of any used in these tests. To the embrittling effects of sigma phase and carbide precipitation must now be added some effect of residual stresses from cold working.

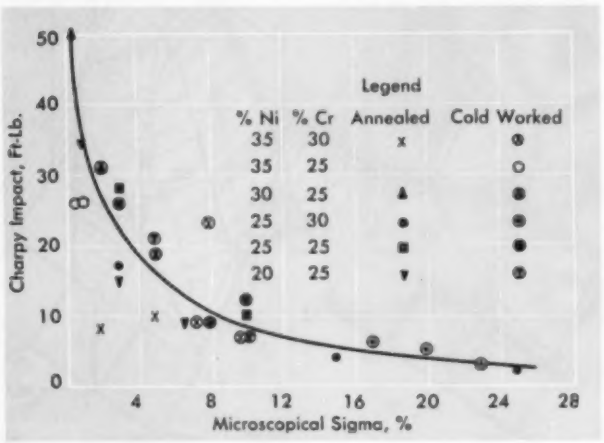
Maximum Percentage of Chromium at Which No Sigma Appears in 3000 Hr. in Annealed and in Cold Worked Ni-Cr-Fe Alloys*

Nickel Content	At 1200° F.		At 1475° F.		At 1650° F.	
	Ann.	C.W.	Ann.	C.W.	Ann.	C.W.
20%	22	21	20	20	21	22
25	25	20	20	20	21	23
30	28	21	22	22	25	25
35	> 30	30	26	26	27	26

*0.05% C, 1.09% Mn, 0.7% Si.

However, it appears most likely that the drop in impact values from those of the initially quench-annealed samples is not due to this added factor of unrelieved stresses *per se*, but to the effect of such stresses in facilitating the ready formation of sigma. In Fig. 4 it will be noted that the 3000-hr. holding at 1200° (the solid line diagram) did not lower the already low values for the 100-hr. heating (the broken line diagram) of the cold worked alloys nearly so much as does the same treatment of the annealed material, Fig. 3, most of the embrittlement having already occurred in the first 100 hr. All of the cold worked alloys, with the possible exception of the 35 Ni, 15 Cr composition (lowest in chromium), were definitely lower in impact values after the 1200° F. reheating than before.

Fig. 5 – Effect of Sigma on Impact Values of Ni-Cr-Fe Alloys, as Determined on Charpy Keyhole Specimens



Effect of Higher Heating – Marked differences between the 100 and 3000-hr. values appear in Fig. 3 for the annealed metal heated to 1475 and 1650° F., particularly when sigma phase was identified after 3000 hr. at temperature. The impact values of the alloys highest in nickel (35%) containing 25, 20 and 15% Cr are improved by the longer holding time at 1650° F.

In fact, the effects of preliminary cold working appear (from the close agreement of the 100-hr. broken line and the 3000-hr. solid line diagrams in Fig. 4) to have been completely annealed out at 1475 and 1650° during the shorter holding time at tempera-

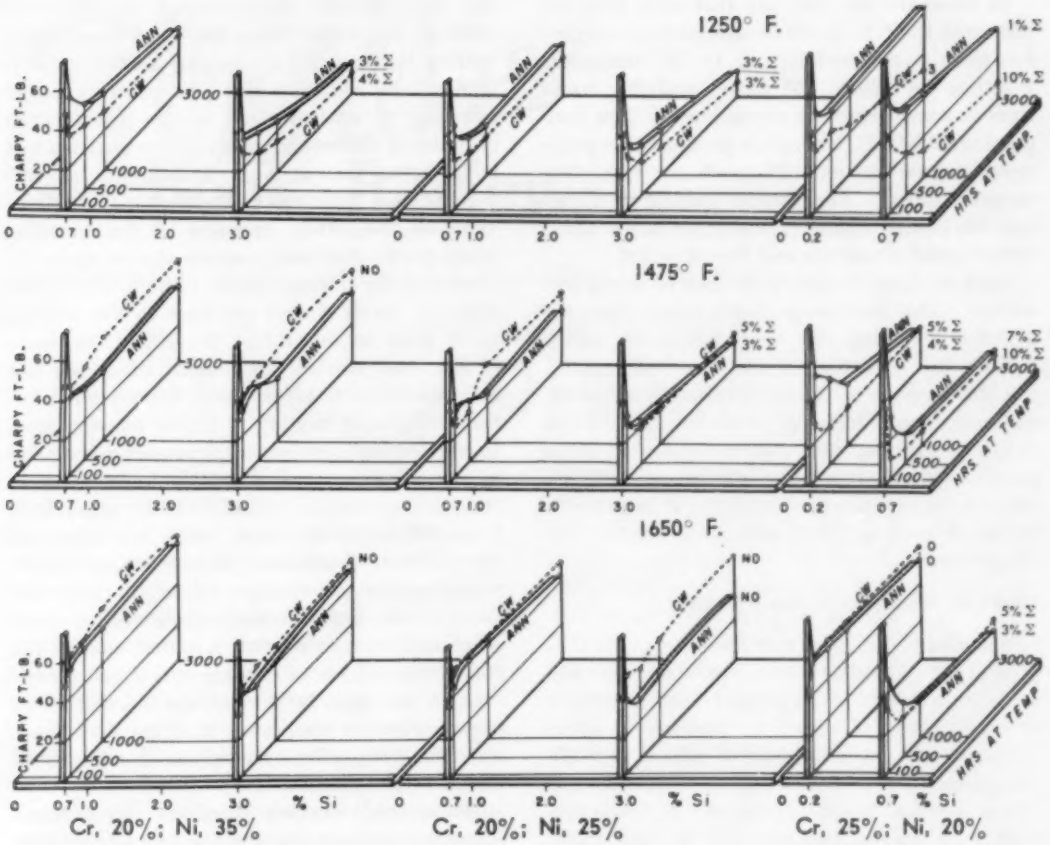


Fig. 6 – Effect of Silicon in Commercial Ni-Cr-Fe Alloys, Annealed or Cold Worked, on Charpy Values After Long Heating Into Sigma Range

ture. There is an unexplained and noteworthy exception to the general pattern of behavior of the cold worked 25-20, 25-25 and 25-30 Cr-Ni alloys after the 1650° F. exposures, Fig. 4. These three alloys show a more pronounced lowering of impact value after 3000 hr. at 1650° F. than after the same time of holding at 1475° F.

There is reason to question the "less than 1% sigma" reported for the annealed 30 Ni, 25 Cr alloy after 1475° F. for 3000 hr. (Fig. 3). Its impact value after 3000 hr. exposure was 50 ft-lb., *higher* than after 100 hr. (43 ft-lb.). The corresponding values for the cold worked metal were 37 and 31 ft-lb. respectively, with a sigma content estimated at 2%. The fact that this alloy transformed to 5% sigma when cold worked and heated to 1200° F. for 3000 hr. suggests the possibility of limited stability of sigma at 1475° but does not explain the improvement in impact value in the annealed material after the long time at higher temperature.

Sigma Versus Impact Values – Amount of sigma versus impact values is plotted in Fig. 5. Considering the difficulties inherent – first of all, in etching so as to reveal sigma and finally in unmistakably identifying and estimating its relative amount – the scatter is not considered unreasonable. The greatest scatter is to be noted with a small proportion of sigma (8% or lower), suggesting that the *location* of the sigma particles may have an influence additive to the actual amount. It seems from Fig. 5 that more than 5% sigma is necessary to "embrittle", defining that word as meaning a Charpy value under 15 ft-lb. Below this content the Charpy value appears to increase rapidly; the effect on impact value of 1% sigma or less is of little practical significance. However, it is indicated, not to say proven, that even very small amounts of sigma have an effect which is measurable in terms of notched impact resistance, even though, as already noted, the values plotted in Fig. 5 are not entirely due to the indicated amount of sigma.

In summary we may say that after long exposure at 1200° F. (3000 hr. and perhaps longer) ferrous alloys containing 15 to 30% chromium together with 20 to 35% nickel probably transform in some degree to sigma phase. This temperature, 1200° F., ultimately produces the maximum degree of embrittlement for the alloy ranges studied. The largest amount of sigma and the lowest impact values occur in the alloys with highest chromium and lowest nickel.

Cold working increases the rate of sigma formation. This increase probably results from the activity attending the recrystallization which follows the reheating of cold worked metal — the stable phase at the recrystallization temperature (sigma) forming most readily. Thus, sigma transformation in cold worked material is nearly completed in only 100 hr. at 1200° F., whereas in the annealed material it appears to be far from completed after 3000 hr. at this temperature.

Effect of Silicon on Sigma Formation

When silicon is higher or lower than the 0.7% present in the alloys just described and the chromium is held at a constant level, a greater or less amount of nickel is required to avoid sigma formation. The effect of silicon in a 20% chromium alloy at two levels of nickel, 25 and 35%, is shown at left and center of Fig. 6, wherein impact values for initially cold worked metal (CW) are shown by the broken line and annealed material (ANN) by a solid line. Percentages of sigma found after the 3000-hr. exposures are also noted.

No sigma was found in any of the 20-35 nor the 20-25 Cr-Ni alloys, annealed or cold worked, after any exposure, when the metal contained 0.7% Si, but sigma appeared in both conditions of the 3% silicon alloy after the 1200° F. 3000-hr. exposure of the 20-35 Cr-Ni alloy and after both the 1200 and the 1475° F. exposures of the 20-25 Cr-Ni alloy for 3000 hr. The same effect is noted in the 25-20 Cr-Ni alloy (Type 310) shown at the right of Fig. 6 in which 4 to 5% sigma appeared after the 1475° F. treatment of the alloy containing 0.20% Si, 3% sigma in the cold worked alloy after 1200° F. for 3000 hr., and none in either condition after the 1650° F. exposure. An increase in silicon from 0.2 to but 0.7% greatly increases sigma formation in Type 310 at all temperatures, but especially at 1475° F.

In Fig. 6 it is interesting to observe that, particularly in specimens without sigma, the dotted lines representing the impact values of the cold worked metal heated to 1475 and 1650° F. are higher than the solid lines representing the values for annealed metal. One is inclined to attribute this consistently benign influence of cold working to the precipitation of carbides *within* the grains of the cold worked metal rather than at grain boundaries.

Associated with this phenomenon is another: Whereas the 100-hr. exposure of the *annealed* metal to elevated temperatures always markedly decreases the impact values (which, even after 3000 hr., rarely if ever get back to the original value prior to reheating) the 100-hr. exposure of the *cold worked* specimens, which do not undergo sigma transformation, increases the impact value after heating to higher temperatures. In cold worked specimens the impact value prior to reheating is quite definitely lower than in annealed specimens. After 1200° F., when little recrystallization or stress relief has occurred, precipitation of carbides (and sometimes sigma) causes further loss of impact strength. Improvement at the higher temperatures due to stress relief and recrystallization is pitted against the embrittling effects of carbide and sigma formation. If no sigma be present, the balance favors improvement in toughness; if sigma does form, its embrittling effect outweighs the beneficial effects of recrystallization.

While cold working promotes sigma transformation in these alloys in the low temperature range, it no doubt also increases the tendency of the sigma to transform back to either gamma or alpha at higher temperatures — both transformations being more sluggish in the unstressed metal. If the cold worked metal is nearly recrystallized prior to the disappearance of the sigma phase, transformation to alpha (or to gamma, as the case may be) may still be accelerated by the nucleation to be expected during the completion of recrystallization.

Increasing the nickel content appears to decrease the temperature at which sigma forms and to narrow the range of temperature in which it is stable. In Fig. 6, sigma is observed to be present in cold worked high-silicon 35% nickel alloy only after exposure at 1200° F., in the 25% nickel alloy after both 1200 and 1475° F. exposures, and after all three exposures in the 20% nickel alloy. While increased nickel, of itself, inhibits sigma formation, it is suspected that it may also lower the temperature at which recrystallization of cold worked metal of this type is completed, and this may partly account for this phenomenon.

Book Review...

Relationship of Physics and Chemistry to Metallurgy

*Reviewed by J. H. HOLLOMON**

THEORETICAL STRUCTURAL METALLURGY, by A. H. Cottrell. 2nd Ed. St. Martin's Press Inc., New York. 1955, 251 p., $4.50.

THE SECOND EDITION of the now-famous text by Dr. Cottrell is a complete revision of the earlier edition. It contains one new chapter, and new information only recently added to the literature of metallurgy is included. Dr. Cottrell has given a sound critical analysis of this new work. The general organization and fine style established in the earlier edition are maintained.

The text begins with a description of the structure of the atom, a description of the forces between atoms and their arrangement, and the structure of metal crystals. It then describes qualitatively the generalizations of wave mechanics as applied to free electrons and thus derives the general electronic properties of solids, particularly metals. It introduces the concept of scattering and of resistance to electrical conduction, and describes the elementary basis of ferromagnetism and cohesion. At this point in the text the approach changes and quantum wave mechanics are almost never (with one exception) mentioned to describe the behavior of metals.

The approach to the constitution of metals is that of classic thermodynamics and thereafter the primary description is in terms of phase equilibrium derived from Gibbs or classical thermodynamics. Then follows a description of long-range order, of domains of order, kinetics of reactions, finally nucleation and growth ideas applied to precipitation and other important metal reactions. The final chapter describes shear deformation processes and the simple theory of dislocations and how important properties of crystals can be qualitatively derived from this simple model of defects in crystals.

The text primarily relates physics and chemistry to metallurgy. Neither the physicist nor the chemist nor the metallurgist will find the book satisfying. The physicist will be disappointed with the treatment of quantum mechanics, physical chemists disappointed by the treatment of thermodynamics and kinetics and the metallurgist disappointed in the treatment of metallurgical processes such as freezing, precipitation and kinetics of reactions generally.

It has been assumed by practically every physicist who has written a text for use by the metallurgist that he needs and should have some elementary understanding of quantum mechanics and its implications even though there is as yet no use for it in describing the properties of real crystals with which the metallurgist is familiar and must work. Nor does this book provide a convenient framework within which to categorize the information and ideas he does get. A superficial treatment of quantum mechanics cannot possibly give a feeling for this discipline as a tool nor can it truly be useful to a metallurgist in arriving at the relationships between properties and metal structure. The metallurgist's realm lies in relating the behavior of metals to their refining, fabrication and economic utilization. This subject currently requires a training primarily in classical mechanics, classical physics, thermodynamics and kinetics. These elementary disciplines give almost all the necessary fundamentals for the treatment of metallurgy – at least the metallurgy of the 1950's and 1960's.

Though the material in Cottrell's book is clearly presented and usefully arranged, it is not a satisfying way to introduce a metallurgist to physics or chemistry; or a chemist or physicist to metallurgy.

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Professor Mehl Has Also Recently Received the Le Chatelier Medal From the French Metallurgical Society

What Is a University Professor?

*By ROBERT F. MEHL**

IF I COULD I'd avoid getting up to speak at this dinner of the American Chemical Society of Pittsburgh, but I have orders to do so. If I should talk about metallurgy probably nearly everyone here would be bored; if I should talk about chemistry most of the wives would be bored – for just think how they have already suffered from their husbands through the years in this way! And if I should talk about research, I'd be speaking of what you know at least as well as I.

So I shall speak on a subject that is not a subject at all. No one could ever find a title for it. I am going to single out some unnamed youngster aged 25 years or so. A lucky fellow, at a wonderful age. A youngster who just, proudly, received his Ph.D. from a respectable institution, and has decided to embrace an academic career. You have known many such young men, and of course are interested in them, so that perhaps these remarks about what their future might be are not inappropriate.

There he is, a young American, vigorous, good-looking, ambitious, a devotee to science, better trained than his predecessors – probably with a

*Dean of Graduate Studies at Carnegie Institute of Technology as well as Head of the Department of Metallurgical Engineering and the Metals Research Laboratory. This article is part of a speech accepting the Pittsburgh American Chemical Society Award on Dec. 12, 1956.

crew cut, married. His clothes are not so conservative as they will be later, when dignities have been forced upon him. Full of confidence, yet nonetheless a little appalled at the future. Will this be the best of all possible worlds?

He's got a job as an assistant professor at a good college, maybe Carnegie Tech. He is going to teach undergraduate and graduate students, and he will try to build a reputation in research also, and later he will do some consulting work. Then suddenly, in September he will appear before his first class. Proud, and almighty scared, with all subsequent weeks and even years confirming his fears, he joins that congregation of scholars which we call the University.

Now our young hero (you see, I think he is a bit of a hero), will have had some professors he admires – despite those occasions when he feels his oats a little, and is skeptical of their *real* ability (as a son often wonders whether his old man really has anything), and he will emulate them, and will want to be like them, at least some of them, when he is older.

But it's a little confusing, for these are very different men – and now he encounters a great truth: Great teachers are great in vastly different ways, each in his own. What did Willard Gibbs have in common with Woodrow Wilson, and what had Woodrow Wilson in common with Agassiz, and Agassiz with John Dewey or William James? Ah, there's a problem for you! None subscribed to an overall form; each was a great teacher in his own way. No educational theory or plan marched them in disciplined ranks. Each was something of a heretic, practicing heterodoxy in his own way, heretical in measure as indeed all university work must truly be if the mind and the store of knowledge should advance. These men *were* very different; Willard Gibbs, a recluse, an ill-mannered man, an impossible lecturer; Woodrow Wilson, a great lecturer on government; Agassiz, a laboratory disciplinarian and perfectionist, a polemicist. Can you imagine Willard Gibbs showing Agassiz' concern with the straining of an undergraduate to learn, or teaching an undergraduate class with the enthusiasm of Woodrow Wilson?

There is no obvious formula here, no fixed method. With all this diversity, what in the name of sense had they in common? Anything? Of course. But not a rigid educational theory. If we can say what they had in common, our young man will have an important sign-post for his future.

Here it is, at least as I see it: Each was a superb scholar, with happiness in that first and great essential, namely, unremitting hard work. None took it as a pleasant way of life – indeed not as a way of life at all, but as a job with a mission. Each had an immense need, even a compulsion, to teach, to find the new, to rationalize the old to a new truth – all this ambition in one of its best forms. Each sought unobtrusive, shy truth which never shouts and must always be sought out.

These must be the aims of our young hero; these positive qualities he must cultivate.

Think of the power that our young hero is about to begin to exert! He deals with the young. Through his classes and those of his colleagues will pass all of the leaders of the future, to be acted upon by him. He will be respected, for earnest effort easily wins the respect of the young. He has the job, among many others, of freeing their minds, of brainwashing them as thoroughly as possible against brainwashing of every and of whatever kind. He must inculcate clear thinking; he must lead his students to consider every aspect of a problem, of whatever sort, and then with the best and most instructed opinion to be ready and willing to act, for thought without action is a most futile thing. In devising his work for students, he must truly lead; he cannot, if he meets his full responsibility, have his students learn only what once was, or even only what now is, unless he should draw from such lessons what will be. He must, in a word, anticipate the future to a degree, for the student must be made to know that this is a *plus ultra* world, with much to come that will be different, and that it is *he* who is now the student who will have to deal with it as a new and yet unsolved problem, with all the reasonableness, clarity of mind, knowledge of basic principles, ingenuity and inventiveness that he can possibly muster.

And as to science itself, let us say immediately that it is not a branch of aesthetics, not a litany nor a creed. It is a live thing, constantly changing, not to be held in a permanent mold. A professor cannot, if he is to be a leading professor, learn some subject thoroughly as of today, and then teach it just so, for the rest of his life. I think this has plagued a number of subjects – perhaps thermodynamics has been vulnerable in this way; it isn't nearly enough merely to determine another free-energy change for its own sake without a greater aim in view. Even an old subject, apparently staid and even finished, is never really finished. It may take an

Onsager, or Debye and Huckel to break out of overproud orthodoxy, but such as do are the real leaders.

Is this a dangerous thing, to adventure and to create new science, and to lead students to do so too? Of course! But then it has been said that when there is no danger a civilization dies, and I think it can also be said that science dies when no risk is taken – and so does a professor!

Now I shouldn't want to say that in a practical, realistic sense one builds a successful university department by means of prima donnas, for some (though surprisingly few) of our great teachers were prima donnas. A department head with a faculty of all prima donnas would go nuts mighty fast. And there is also yeoman work to do. Cooperation is necessary, curricula must be planned and correlated, committee meetings (which incidentally, despite common opinion, are far less frequent in the university than in many an industry) must be attended. There is yeoman work in every job; even a minister has his parish affairs to attend to. But however one might argue all this, one comes back – at least I do – to this, that these are the qualities that can be identified in the great teacher, and are present in every good teacher – to lead, to free minds from prejudice, to inculcate clear thinking, to teach his subject as a living, growing thing.

These are the very qualities that have always been valued in teachers, that have always been most valued in the university. They are those to which every, I repeat, *every* teacher should aspire and strive. These old values must be preserved in our universities now, and kept in the times to come. Occasionally there will be an ivory tower, so that we may have a Willard Gibbs, and in the whole pattern the university must have a place for them, giving them that most valuable commodity of all – time. The old virtues, proved and proved again and again, must be preserved.

I know that the professor these days faces a different scene than he did, say, 50 years ago. In many ways he must be a different chap than he used to be. Now many demands are made on him, by industry, by the government, by the exigencies of new science that often for his own purposes require cooperative effort and large expensive apparatus. He has finally reached that public position in the affairs of men that he always thought he should have but never quite managed. Let those old qualities, old circumstances that led to a Newton, a William James, be kept, but married to the new.

I am quite sure that the older days were simpler – I know, for I lived as a young man in a simpler day. But I do not believe that the older days were ideal. There was too little of everything then, the pace was really too slow, even lethargic, with too little of the adventurous. Today, taken in all, is much better. One has a wide range of possible interests, with money (from the government primarily) to pursue nearly anything he wishes. In my view, the net gain over the old days is very great indeed.

Well, *there* is the future for our young hero. A college professor in his best incarnation is quite a chap. If our young man has a promise of the qualities one wants, he surely should elect such a career. Even if he wants a career in research in basic science in addition to teaching, the university is his natural habitat. Despite the attractions of industrial work, despite the extraordinary opportunities in basic and theoretical work with which some industries at the moment tempt away the best young men, I submit that all this cannot be the natural task of industry. Industry has other needs, other great responsibilities, and it has other and very great victories.

But in many ways, the university is the embodiment of civilization, it is long-lived, it has persisted despite changes in kings, political attitudes, wars and revolutions, through a thousand years, essentially unchanged in its aims and in its mission – to teach and to learn. Its place is deeply inherent in any social system; it has contributed to civilization beyond measure; its place in society will last long.

There it is, the university. Take a long look at it. These days, it is having troubles, but it knows its job. Since Americans like crusades – wouldn't it be wonderful to see a crusade for education arising in America, to see Americans supporting education fully instead of admiring it only, so that we might have many more great teachers in America. Our young hero is in that university, laboring pretty hard, as everyone does. We ought, as a nation, help him in every possible way so that the university might become the powerful force that thoughtful and knowing men have always envisaged.

Well, that's my talk. It isn't really a speech at all. It's a sort of panegyric for education and the university, I realize, with a lot of purple passages. I can't imagine a better place to talk about such a subject than a Society which has always stood for intellectualism at its best and for the best in education.

Atmospheres for Sintering Furnaces

*By N. K. KOEBEL**

Powder metal compacts consist of such tiny fragments – have such large surface-to-mass ratio – that sintering must be done in highly protective atmospheres. These are generated in the same types of equipment as widely installed in modern heat treating departments. (H15q, 1-2)

ANY INCLUSIVE ACCOUNT of the sintering of powder metal compacts would comprise three discussions, namely, what happens to hot particles of metal in close contact, protective atmospheres and method of generation, and the specialized furnaces in use. In this article the first two topics will be briefly considered, leaving the third for the next issue of *Metal Progress*.

Theory of Sintering – Sintering is academically defined as the bonding of solid bodies by atomic forces in which such bonding is facilitated by pressure and heat. At first glance this seems to be a rather high-class definition, but if we look at it carefully we find it reveals the fundamental of powder metallurgy.

From the statement in the above definition that pressure facilitates sintering, we can suspect that the purpose of the press operation in powder metallurgy is not only to form a compact of definite shape, but also to produce strong adhesion bonds at the contacts between adjacent particles. Thus, the press operation is essential to sintering and is actually the start of sintering. The compact coheres not only because of mechanical interlocking of particles, but also by interatomic attraction.

To put this statement in terms used by the shop man, the powders become "cold welded" to a certain degree during the press operation. An example of cold welding with which we are

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all familiar is the adhesion of steel to a die by what is called the galling action of the steel part being drawn. Once a die has loaded up by galling, only grinding or stoning will remove the particles of steel cold welded to the die by pressure.

Although a very important factor in sintering, pressure alone does not cause enough sintering to impart useful properties to the compact — in fact, it must be handled carefully to prevent damage. An increase in pressure beyond a certain point does not give added strength or bonding to this "green" compact. In fact, too much pressure may cause the compact to crumble or split at an angle to the direction in which the pressure was applied.

Heat and the proper protective atmosphere are essential to give the compact strength and useful physical properties. Therefore, from the practical point of view, the sintering operation may be defined as the processing of the green pressed compacts in a protective atmosphere for a time and temperature to impart useful properties to the compact.

Powder metal products to be sintered may be divided broadly into two classes, the first comprising those combinations of metals which when heated form a liquid constituent, and the second including those which do not. An example of the first class is the porous bronze "oilless bearings" made of copper, tin and graphite sintered above the melting point of tin. Still another example is the cemented carbides used widely for tools, where sintering is conducted above the melting point of the binder metal, which may be cobalt. Examples of the second class are compacts made from iron powder, copper powder, or tungsten powder.

We should not get the idea from our definition of the first class of metal powder compacts that sintering metal objects is similar to sticking grains of sand together with mortar. In bronze bearings, the tin indeed does melt, but it does not stay at the surfaces of the copper particles, it alloys throughout them, and the newly formed copper-tin particles recrystallize to form a new network of grain boundaries. In "cemented carbides", the tungsten carbide particles do not recrystallize, but a small amount of carbide at each contact intermingles, so the separating surface disappears. This is exactly what happens when a compact made exclusively of iron particles is sintered. Furthermore the binder metal dissolves a slight amount of the solid; the liquid metal binder (cobalt in this instance) is actually needed to facilitate bonding. Cemented carbides, so-called, are therefore somewhat misnamed; the metallic liquid phase is much more than a cement, and the particles themselves (inert in a concrete aggregate) actually interdiffuse at contacting surfaces. This statement is generally true for that large class of powder metal products called "cermets" where one phase is a metal or metallic alloy and the other phase (or phases) is a metallic compound.

Table I — Approximate Sintering Temperatures and Times

Material	Temperature, °F.	Time, Min.
Bronze	1400 to 1600	10 to 20
Copper	1550 to 1650	30 to 45
Brass (80-20)	1550 to 1650	30 to 45
Iron	1850 to 2100	30 to 45
Nickel	1850 to 2100	30 to 45
Stainless steel	2150 to 2300	30 to 45
Alnico magnets	2200 to 2375	120 to 150
Tungsten carbide	2600 to 2700	20 to 30

In compacts made of a single metal, such as iron or copper or tungsten, the powder may be pressed dry without lubricants or binders and the particles will completely combine and recrystallize below their melting point. Thus, the sintering of powders is the bonding of solid particles by atomic forces; sintering results in solution and recrystallization, much more than mere cementing.

The properties of a sintered object depend upon the type and mesh of the powder, the pressure used in compacting, and the temperature, time and atmosphere of sintering. An object may designedly be very porous, or it can be made to approach very closely the theoretical density. Generally speaking, the greater the pressure, the higher the sintering temperature and the longer the sintering time, the more dense the final metal compact will become.

The sintering temperature and time are, therefore, dependent upon the materials used and the properties desired (See Table I.) Generally speaking, the temperature is about two thirds the melting point of the metal powder; however, a higher temperature is frequently used and it may be only slightly below the melting point if a dense structure is desired. Time at temperature may vary from minutes to hours. We can readily see that there will be no one type of furnace or furnace design to meet all the requirements of sintering metal powders.

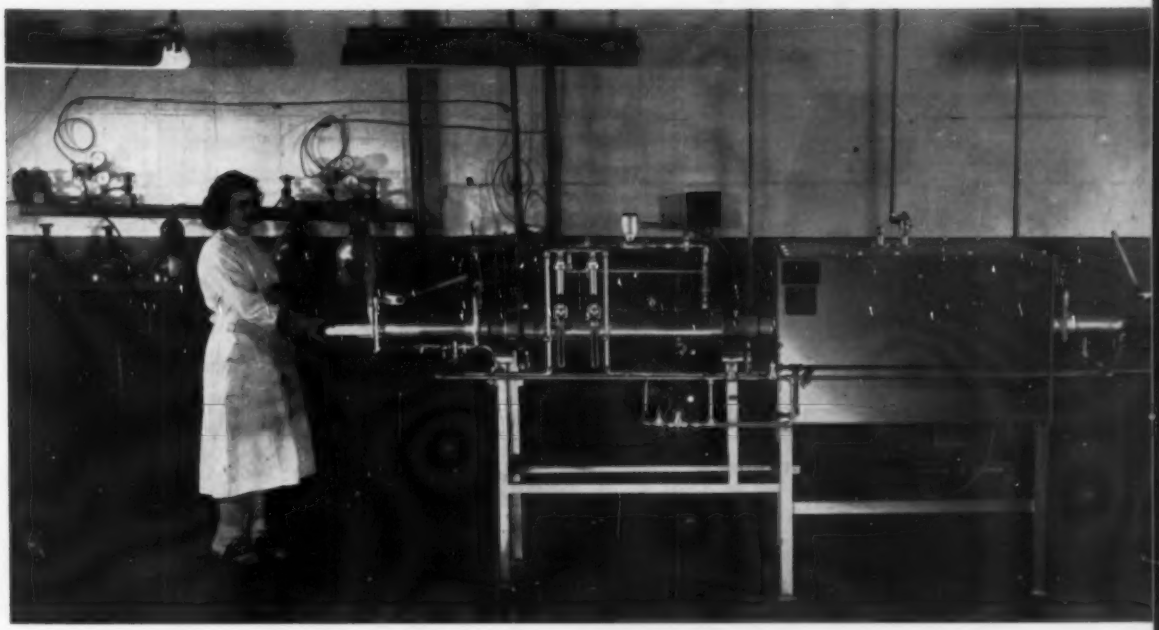


Fig. 1 — Full Muffle Hydrogen Sintering Furnace

Sintering Atmospheres

A proper protective atmosphere is obviously essential. Powders will not sinter properly if oxides or other surface films are present. The primary function of the protective atmosphere is to prevent oxidation at the sintering temperature and also to reduce any oxides that might be present on the powders when they are pressed. (Exceptions, of course, are the cermets containing oxides or other compounds; strictly neutral atmospheres are therefore the rule.)

Reducing atmospheres are therefore generally used. Vacuum sintering is costly and used only on a small scale in very special cases that require it, or for research purposes. An inert atmosphere cannot reduce oxides or surface films that may be present on the pressed powders as they enter the furnace, nor can it burn up and eliminate air carried into the furnace in the porous compact or through the door when charging a load. Furthermore, an inert atmosphere free from traces of oxygen, water vapor and other undesirable constituents is very costly. For these reasons, inert atmospheres are not used commercially in powder metallurgy.

The choice of a reducing atmosphere is dependent upon the material to be sintered, the initial cost of the atmosphere generator, and the operating cost of the generator. The various atmospheres are *(a)* cylinder hydrogen, *(b)* cracked anhydrous ammonia, *(c)* exothermically cracked gas, either as produced, dried to 40° F. dew point, or purified of CO_2 and H_2O, *(d)* endothermically cracked gas. These will now be described.*

Hydrogen — Pure, dry hydrogen is an all-purpose sintering atmosphere. It has the greatest reducing power of all of the protective molecular gases. Hydrogen can be purchased in cylinders containing about 200 cu.ft. at a cost of $10 to $12 per 1000 cu.ft. (measured at atmospheric pressure). Cylinder hydrogen contains traces of water vapor and oxygen and for applications that require *pure* hydrogen, these traces must be removed. The high cost limits its commercial use to items which really require it, or in very small furnaces where one does not wish to buy an atmosphere generator. In some instances, a chemical plant may be nearby and inexpensive byproduct hydrogen can be used.

Pure, dry hydrogen must be used for sintering tungsten carbides and tantalum carbides, molybdenum and other refractory metals, Alnico, stainless steels, or any alloy powder containing over 1% chromium or high in aluminum. Chromium will form an oxide in hydrogen if the dew point of the gas is above −20° F. (0.05% water vapor).

*Somewhat more extensive information may be had in "Types of Furnace Atmospheres," by Curtis H. Vaughan, *Metal Progress*, February 1957, p. 93.

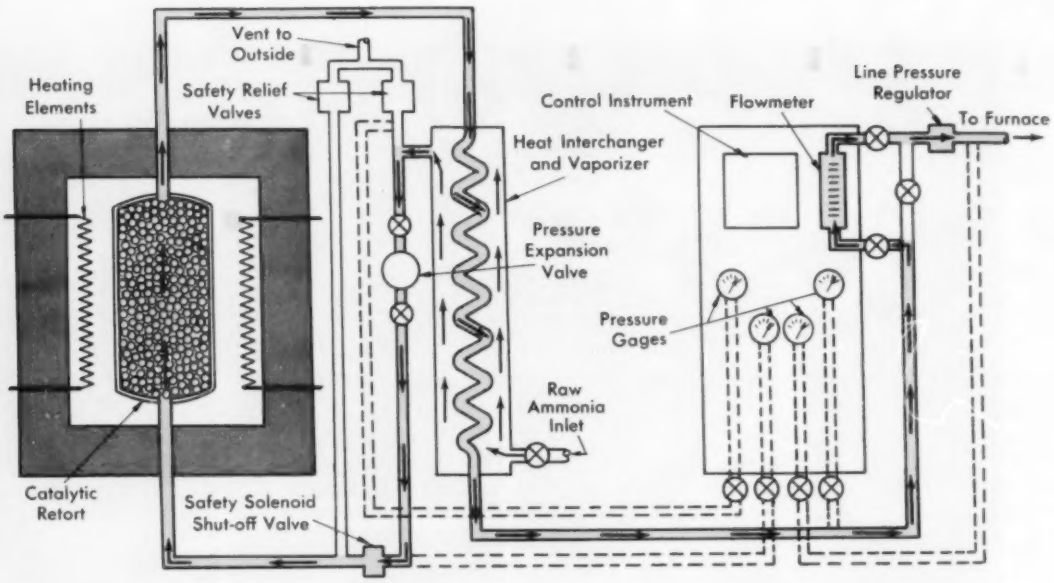


Fig. 2 – Schematic Flow Diagram for Ammonia Dissociator to Generate Hydrogen-Nitrogen Atmosphere

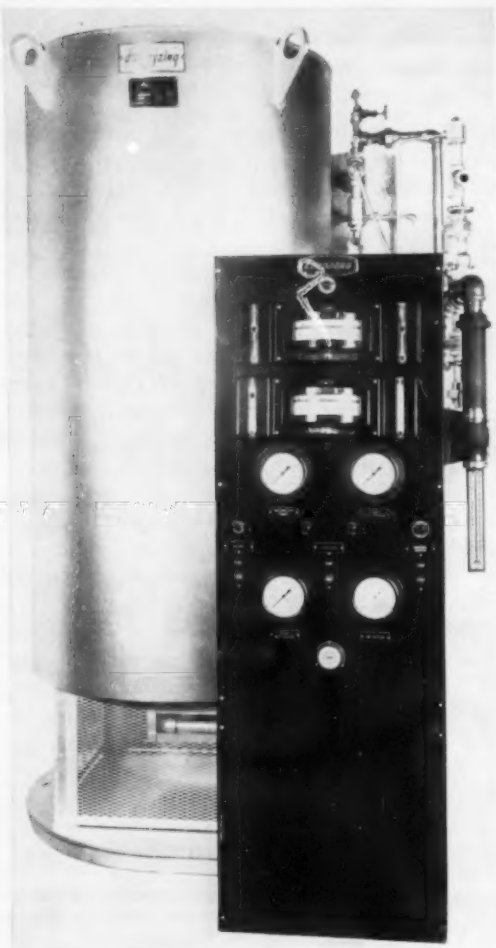


Fig. 3 – Ammonia Dissociator Capable of Producing 1500 Cu.Ft. per Hr. of Hydrogen-Nitrogen Atmosphere

Finally it should be remembered that hydrogen will decarburize iron or steel powder.

In order to keep the hydrogen this dry *in the furnace*, small muffle furnaces are usually employed, such as the one shown in Fig. 1.

Cracked Anhydrous Ammonia – In sintering operations where a high-hydrogen atmosphere is required, it is economically advantageous to produce it by cracking anhydrous ammonia. An atmosphere containing 75% H_2 and 25% N_2 (by volume) is produced by passing the raw ammonia over a heated catalyst. Since no air is used in the cracking process, the resulting hydrogen-nitrogen mixture is free from oxygen or water vapor. The dew point of the cracked gas measures from –40 to –60° F. (0.0188 to 0.0056% water vapor) and is considered "bone dry". A well-designed dissociator will pass a maximum of only 0.05% of NH_3 (undissociated ammonia) when operating at full-rated capacity.

Operation of the dissociator is simple. When cylinder ammonia is used, the workman connects several 150-lb. cylinders to the supply manifold. One cylinder is drained while the others are stand-by. The liquid ammonia flows into a heat interchanger and vaporizer (see the flow diagram, Fig. 2) where it is gasified, and its pressure

reduced to about 7 lb. gage by the pressure expansion valve. The gas then passes through the catalytic chamber, which is heated to 1750° F. by fully automatic devices, using either electric energy or combustion of gas. The hot dissociated ammonia (hydrogen-nitrogen mixture) then passes through the heat interchanger, where it gives up most of its sensible heat to vaporize the incoming liquid ammonia, and finally passes through the flow meter on the control panel, through the pressure-reducing valve and thence to the furnace.

When ammonia arrives by tank car or truck, the necessity for changing cylinders is completely eliminated. To start the generator, the operator presses the proper button on the control panel and adjusts the pressure expansion valve. As soon as the catalytic chamber reaches 1750° F., the protective atmosphere is available for use. Once started, the operation is fully automatic. Automatic control and safety devices are installed to prevent dangerous pressures from being built up in the system. Signal lights and alarm bells immediately warn the operator of any abnormal operation. Equipment is quite compact, as shown by the photograph of a typical dissociator in Fig. 3.

This is an economical method of producing a dry hydrogen atmosphere. When using cylinder ammonia costing 18.5¢ per lb. the resulting cost of the atmosphere (including the cost of operating the dissociator based on electric power at 1¢ per kw-hr.) is $4.28 per 1000 cu.ft. Truck-delivered ammonia in bulk at 9.5¢ per lb. produces ammonia at $2.28 per 1000 cu.ft. This requires a 2500-lb. storage tank at a cost of $2000 to $2500, but such an installation pays for itself in very short time if ammonia can be delivered by truck.

The cost of dissociated ammonia can be reduced to as low as $1.28 per 1000 cu.ft. when using tank car ammonia at 5¢ per lb. This lucrative saving cannot be realized, however, without a much higher initial investment. The first requirement is a railroad siding and spur track to the site of the storage tanks. The second requirement is the necessary storage tanks, compressor for emptying the tank cars, and a vaporizer. This equipment is usually housed in its own building which, of course, costs money and requires ground space. All in all, the initial investment runs from $25,000 upward, and hence tank car ammonia is used only where large dissociators (1500 cu.ft. per hr. or larger) are required and can return the initial investment by savings in a reasonable length of time.

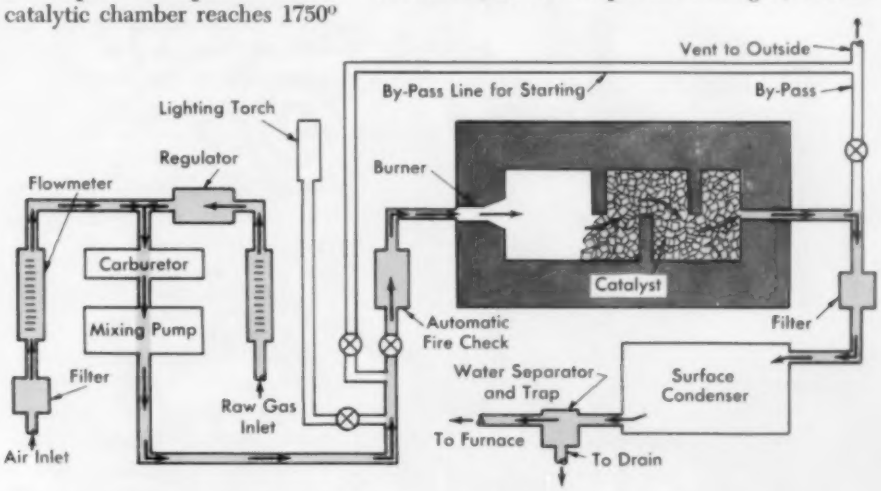


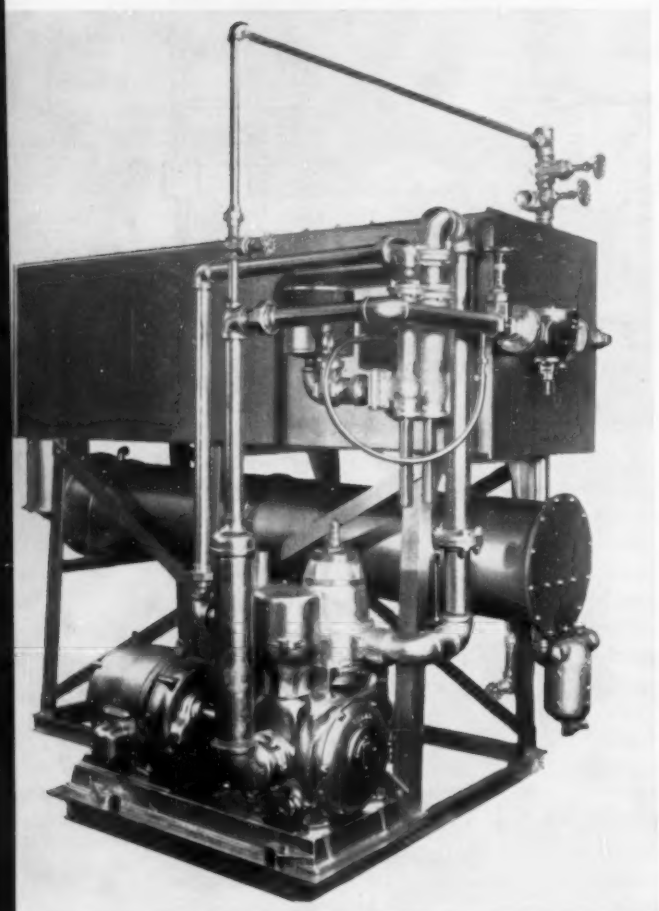
Fig. 4 – Schematic Flow Diagram for Exothermic Atmosphere Generator

One of the principal uses of dissociated ammonia atmosphere is for the sintering of brass compacts; it gives equally good results as pure hydrogen at a great saving in cost. Many powder metal producers feel that dissociated ammonia or hydrogen gives the optimum properties in brass parts, but the two atmospheres cannot always be used interchangeably. For example, tungsten carbide, tantalum carbide and refractory metals require pure hydrogen gas because the molecular nitrogen in dissociated ammonia combines with these powders to form nitrides. This is also true of Alnico. Stainless steels can use $H_2 - N_2$, however, if an increase in

nitrogen content is permissible. Even at best, stainless steel compacts present quite a problem; pure hydrogen will remove the normal nitrogen in solution in the stainless powder and since nitrogen is an element which stabilizes the austenitic microstructure, and since fully austenitic microstructure has definite (and often desirable) characteristics, the nitrogen-free part may be unsatisfactory. A newcomer in the field of powder metallurgy might well skip the manufacture of parts of stainless until he has obtained experience in the sintering of other metals. Finally it should be said that cracked ammonia, as well as pure hydrogen, decarburizes steel and iron powders.

Exothermic Gas – The cheapest atmosphere used for sintering a limited variety of metal powders is produced by exothermically cracking a hydrocarbon gas – such as city gas, natural gas, propane or butane–with air. As shown in Fig. 4, gas and air are metered and mixed in the compressor and pumped into the combustion chamber. There is not enough air for complete combustion, but partial burning raises the temperature of the combustion chamber to about 2000° F. The remaining unburned hydrocarbon then reacts with the products of combustion while passing over the hot catalyst to produce hydrogen and carbon monoxide. The water vapor in the resulting gas mixture is separated in a surface condenser cooled by water.

Fig. 5 – Exothermic Atmosphere Generator for Producing 5000 Cu.Ft. per Hr.



Such an exothermic atmosphere consists of 17% max. H_2, 10% max. CO, 4.0% min. CO_2, balance nitrogen; its dew point is approximately 10° F. higher than the temperature of the cooling water. The atmosphere can be made leaner or less reducing by using less gas and more air, but this is not done for sintering, as it is desirable to get as strong a reducing atmosphere as possible. A photograph of an exothermic generator is shown in Fig. 5.

The exothermic atmosphere is used chiefly as a cheap atmosphere for sintering low-carbon iron powders (if decarburization is unimportant), copper, bronze, silver and nickel powders. The gas is produced at a cost of approximately 8 to 12¢ per 1000 cu.ft., depending on the cost of fuel gas in the vicinity (48¢ to 72¢ per 1000 cu.ft. of 1000-Btu. gas). If sulphur in the fuel gas exceeds 8 grains per 100 cu.ft., scrubbers must be added if it is to be used for sintering copper, bronze, or silver. (The sulphur is removed by passing through a water scrubbing tower to remove any traces of SO_2 and then over a hydrated iron oxide to remove the H_2S.) Generally, sulphur is low enough in natural gas and most refined grades of propane and butane so these sulphur scrubbers can be omitted. City or manufactured gas may run high in sulphur, and scrubbers are generally added as a safeguard when using such fuel.

Partially Dried Atmosphere – When using exothermic atmosphere for sintering iron powders, the gas is often further dried by refrigeration to a dew point of 40° F. In fact, refrigeration is the normal practice when cooling water is above 60° F. This lower content of moisture is necessary to prevent discoloration or oxidation of the part when it cools from 900 to 500° F. In this temperature range, the iron surface acts as a catalyst to promote the reaction $H_2O + Fe = FeO + H_2$. To prevent this, the ratio between the water vapor and hydrogen, H_2O to H_2, must be 1 to

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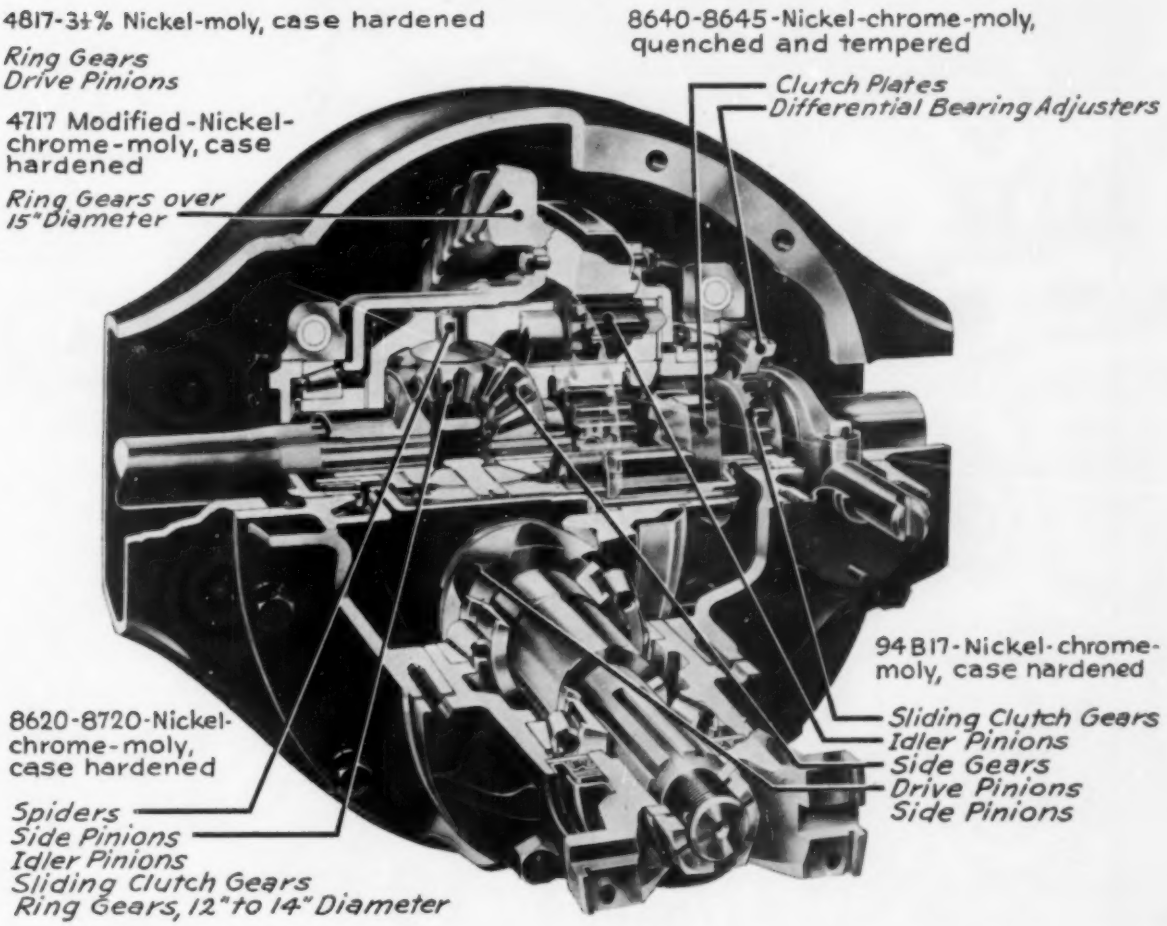

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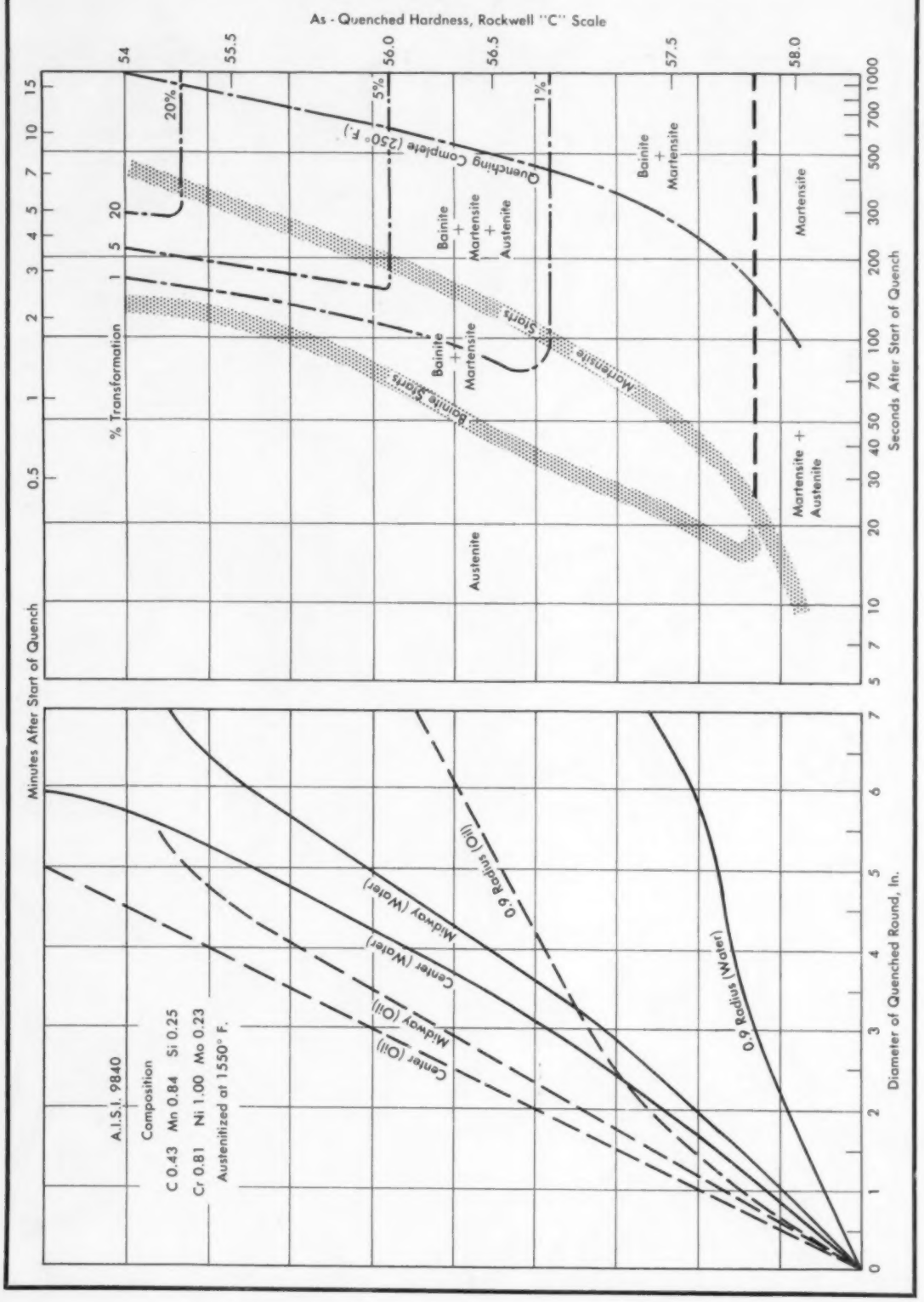

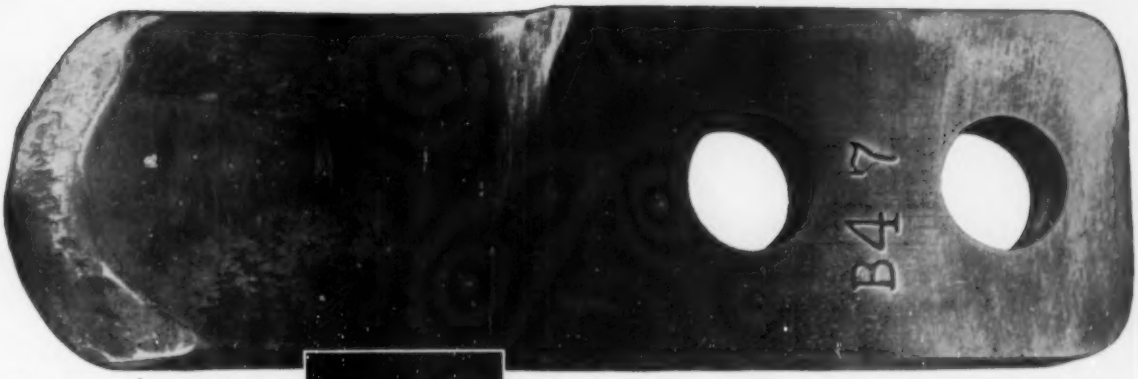

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B-47 punches, vs. low-carbon 18-4-1 type, hot pierced more than twice as many eyes in steel axes. See top picture.

B-47 die inserts, vs. 9% tungsten types, hot pressed more than twice as many steel side gear forgings. B-47 die inserts, vs. regular insert material, performed better than 5 to 1.

B-47 dummy blocks, vs. 5% tungsten-5% chromium types, extruded twice as many copper and brass tubes and rods. B-47 dies outperformed 12% tungsten-12% chromium type.

B-47 punches, vs. 5% chromium type, hot extrusion forged 1½ times as many automotive steel front axle spindles.

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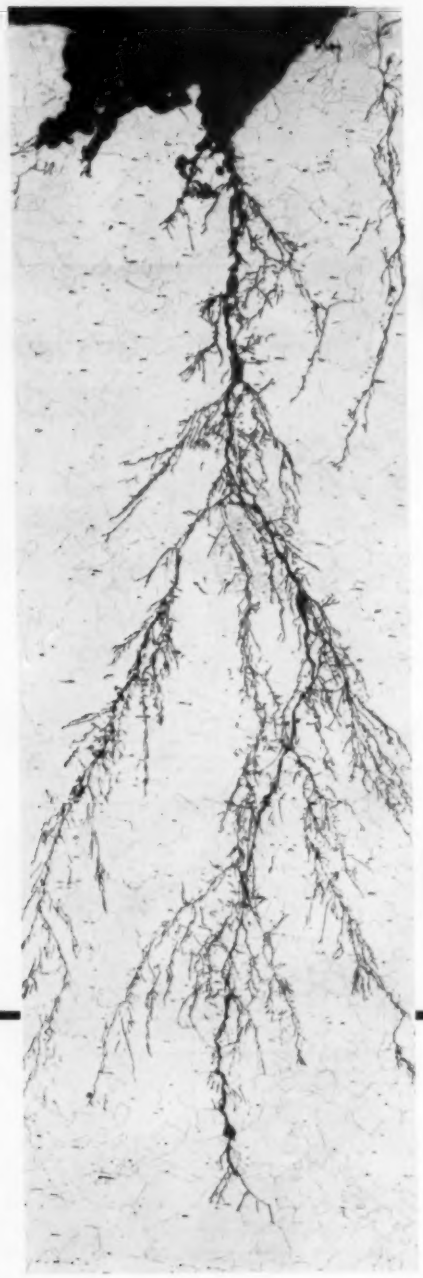

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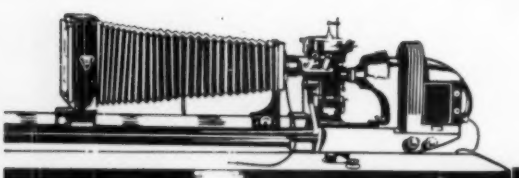

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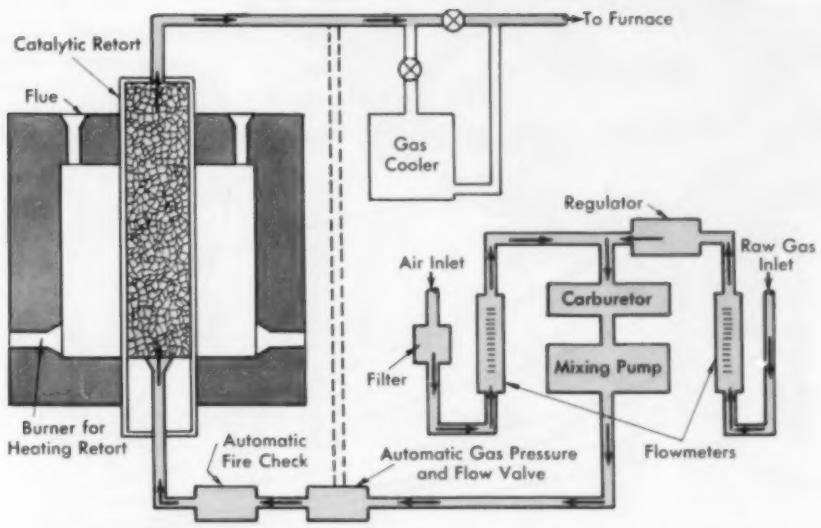


Fig. 6 – Schematic Flow Diagram for Endothermic Atmosphere Generator

20 if the sintered iron load is heavy and the parts cool slowly. If the cooling rate is fast, the ratio may be 1 to 15. (The above reaction occurs only on iron and one need not dry the gas for copper, bronze or silver.)

Refrigeration of the exothermic atmosphere increases the cost of the gas by about 2¢ per 1000 cu.ft. (if cooling water costs no more than 10¢ per 1000 gal.), but the initial cost of the equipment is increased considerably.

Enriched Atmosphere – The above atmosphere, produced by exothermically cracking city or natural gas with air, can be used only for sintering low-carbon powders. The CO_2 and H_2 in the presence of a little H_2O will decarburize high-carbon iron and steel powders very rapidly. Likewise, the CO_2 and H_2O oxidize the zinc in brass mixtures, resulting in low physical properties in the finished part. The undesirable oxides can be removed from the gas by scrubbing out the CO_2 with mono-ethanol-amine and drying the resulting gas to a -60° F. dew point by passing over activated alumina.

This type of gas processing equipment is not used to too great an extent in the powder metal field. The chief reasons are, first, high initial cost (17 to 25¢ per 1000 cu. ft.); second, operation of equipment requires more attention than endothermic generators; third, the resulting gas has only half of the reducing constituents as are contained in the endothermic gas, later to be described; and fourth, the carbon potential of the atmosphere is not readily adjustable.

Endothermic Gas – In order to prevent decarburization of high-carbon iron powders, an

Fig. 7 – 570-Cu.Ft. per Hr. Endothermic Atmosphere Generator

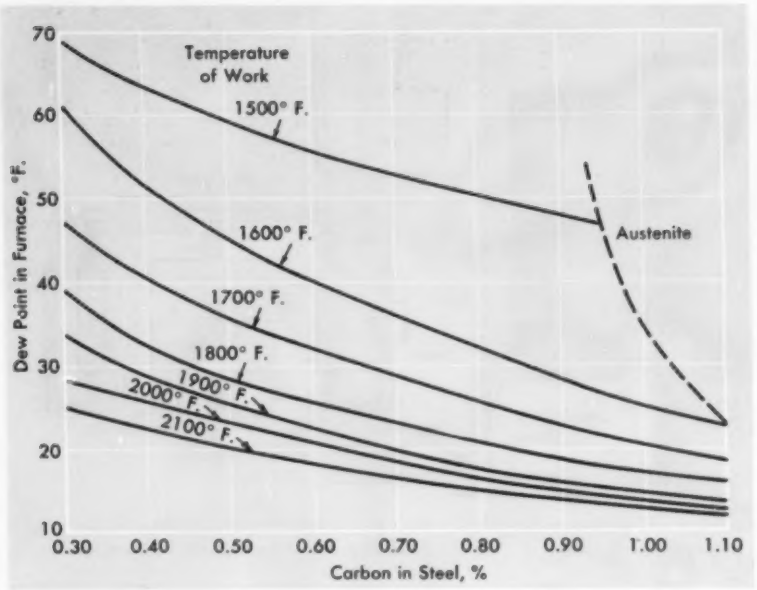


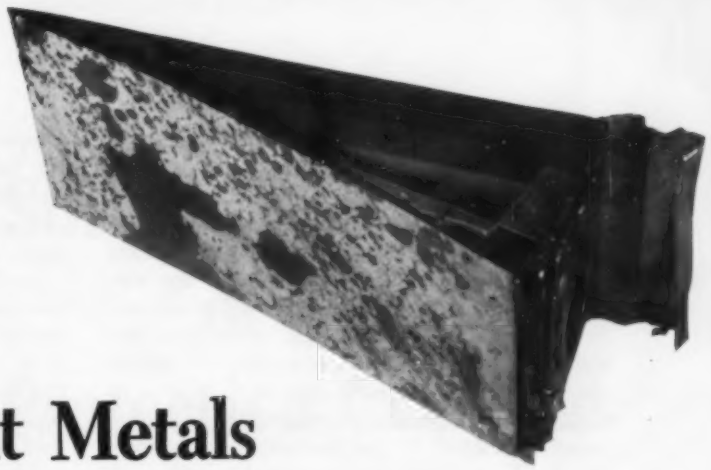
Fig. 8 — Equilibrium Relationship Between Straight Carbon Steels and Dew Point of Endothermic Atmosphere

atmosphere with a controlled carbon potential must be used. This is most conveniently produced by cracking natural gas or propane endothermically with air to a gas mixture free of decarburizing constituents. As shown in the flow diagram, Fig. 6, the gas and air are metered in the proper proportion and then mixed and compressed. The gas-air mixture is passed over an externally heated catalyst bed. The air reacts with the hydrocarbons to produce approximately 40% hydrogen, 20% carbon monoxide, 0 to 3% carbon dioxide, 0 to 1.0% methane, and balance nitrogen, with a dew point that can be varied from zero to 70° F., the variations being controlled by the proportions of gas and air fed into the retort. As the gas leaves the generator it is cooled only for metering, because the H_2O content is controlled in the cracking process to the degree desired and there is no excess to be condensed out in the cooler. A photograph of an endothermic generator is shown in Fig. 7.

The chief difference between the endothermic and the exothermic process is that external heat is used to heat the catalyst and a ratio rich in gas can therefore be cracked with no combustion taking place in the catalytic chamber. Since no combustion takes place as such, the normal products of combustion, carbon dioxide and water vapor which cause decarburization, can be eliminated or reduced to any desired percentage. Furthermore, the carbon potential of the atmosphere can be adjusted to be in equilibrium with any carbon content steel as shown in Fig. 7. For high-carbon powders, the carbon dioxide is kept at zero and the dew point controlled to the desired point as shown on the equilibrium chart.

The endothermic atmosphere costs from 20 to 30¢ per 1000 cu.ft. depending upon the cost of the fuel gas (48 to 72¢ per 1000 cu.ft.). It should be noted that the endothermic atmosphere has 60% reducing constituents as compared to only 27% in the exothermic atmosphere. Because of this many prefer it even for sintering copper, bronze and the low-carbon iron powders. For the same reason it has also been used successfully for brass powders when its dew point is 30 to 40° F. in the furnace; comparable properties have been produced on brass compacts with those sintered in the much more expensive dissociated ammonia.

The endothermic atmosphere is the best all-purpose low-cost atmosphere for sintering in production powder metal parts of iron, copper, bronze and brass, as mentioned, and also of silver and nickel. Although the generator costs about twice as much as the exothermic generator, the atmosphere it produces is necessary for sintering medium and high-carbon iron powders without decarburization. It is also used as a carrier gas for carbo-nitriding and carburizing or neutral hardening of sintered iron parts. If the exothermic generator requires a refrigeration unit, then there is little difference in cost between the two generators in small sizes.



Piece of Airplane Wing After Supersonic Flight. Interior was cooled by air blast; double skin is of laminated construction. Originally the outside surface was covered with a heat-reflective white coating

Heat Tolerant Metals for Aerodynamics

*By WILLIAM M. CANTERBURY**

In his introduction to the conference held by ASME Albuquerque and Los Alamos Chapters, General Canterbury notes that stainless steels are needed for sustained flight above Mach 3.3, that cermet turbine blades are required for high-efficiency engines and the only reason we can build rockets is that their life is measured in seconds. (T24; SGA-h, SGB-a)

MILITARY AVIATION is one of the most competitive enterprises in the world; it is also among the most expensive. Approximately 27¢ of every Federal tax dollar is used to develop and maintain our air power. Obviously, any improvement in aircraft materials would help to protect this investment and aid our defense programs. Pooling of ideas, such as is the objective of the "Conference on Heat Tolerant Metals for Aerodynamic Applications", cannot help but promote these objectives.

Among the most pressing metallurgical problems facing the Air Force are those involving high-temperature environments. The need for high speeds is obvious; however, aircraft speeds are limited not only by the usual aerodynamic problems but also by thermal considerations. Both aerodynamic heating and power plant efficiency are vexing limitations.

When the sonic barrier (Mach 1) was first surpassed in the mid-forties, there was no aerodynamic heating problem. But as planes began to fly slightly faster, the problem was upon us. The first solution was found in high-strength aluminum alloys, designed specifically to meet aircraft requirements. Aluminum alloys enable us to fly slightly over Mach 2 at high altitudes, which is fast enough for our present operational aircraft. Experimental airplanes, which foretell combat operational requirements of the near future, will require metals with greater strength and heat resistance than aluminum alloys can give us.

The need for light alloys which can retain the required strength at high temperatures prompted our Government to spend approximately a billion dollars on the development of titanium and its alloys. Commercial titanium alloys can be used at approximately 800° F., representing stagnation skin temperatures for aircraft speeds of about Mach 3.3 at 40,000 ft. altitude or greater. Recent developments in titanium alloys show promise of extending their usefulness somewhat above this temperature.

At greater speeds we are at present forced to

*Brigadier General, United States Air Force Special Weapons Center, Kirtland Air Force Base, Albuquerque, N.M.

resort to stainless steel, for which we pay a terrific weight penalty. Nevertheless, this metal enables us to fly faster than Mach 3.7, at which speed the stagnation temperature exceeds 1000° F. We can make short dashes at these speeds with our present structural materials, but sustained flight is impossible; the dash time may be restricted to seconds, and even then the cumulative effects limit the number of dashes that can be made by each airplane.*

Soon we will need materials which will resist more than 1500° F. and permit us to fly over Mach 4.5. As alloys are developed to withstand higher temperatures, research to improve structural materials for operation at conventional temperatures must also continue. We will always desire alloys which are lighter, cheaper and stronger.

Engines — A parallel problem of great concern to the Air Force is that of obtaining metals to withstand the high temperatures and stresses generated in modern jet and rocket engines. If these engines could be operated at higher temperatures, we could obtain more thrust per pound of engine and per pound of fuel. Total thrust goes up in almost linear relation to temperature of turbine blades. In this respect considerable progress is being made. In 1946 we were forced to hold turbojet temperatures below 1000° F. in order to obtain a reasonable life of engine. We now have operational aircraft with engine components withstanding temperatures around 1500° F., and the new cermets have made it possible to operate experimental jet engines considerably above this temperature.

With rocket engines we are generally not worried about creep, fatigue failure, or slow corrosion — those factors which usually limit turbojet engines. In rocket engines, particularly those of the expendable missile type, melting point of a metal or decomposition temperature of a compound may become the limiting variable. (The relationships of thrust and efficiency to operating temperatures are about the same for rocket propulsion units as for jet engines.) The temperatures in rockets are much greater, but the time of exposure is generally much shorter. Nevertheless, at the present time rocket engine efficiencies are limited by material characteristics rather than by the capabilities of the fuels.

Another heat problem is associated with the intercontinental ballistic missile (ICBM). Its speed during re-entry into the earth's atmosphere is so great that temperatures are developed in the nose section which no structural material could withstand for long. Fortunately, the short time of flight through the atmosphere makes this problem solvable. However, missile materials are needed which, in addition to refractory characteristics, have the strength properties needed to withstand the structural stresses of flight, plus the ability to provide the thermal protection required for the cargo or warhead. One solution is to use large amounts of metal to provide structural strength and serve as a heat "sink", but each pound in a ballistic missile is costly in range and pay load. A better solution must be devised. The sooner the problem is solved, the faster our ICBM capabilities will advance.

Another area in which the Air Force encountered serious problems in the materials of construction is in nuclear power plants for aircraft. We can have almost unlimited power from a nuclear engine. If it is to be harnessed for propulsion, this energy must be passed through some material in the form of heat. Such materials may be required to withstand temperatures far beyond present requirements, if we are to utilize the tremendous potential of nuclear energy. In addition to high heat and severe stress, the materials used for this purpose will also be bombarded by high nuclear flux.

The thermal problems associated with aerodynamic phenomena and propulsion engines can to some extent be circumvented by special design techniques. Critical areas can be cooled by fuel or air flow; transpiration cooling may be used. A number of proprietary designs and classified techniques also are available. Nevertheless, improvements in the materials are still needed, because, despite the best that designers can do, the speed, efficiency and endurance of aircraft are limited by materials from which the structure and the power plant are built.

Although I have mentioned only a few of the problems facing the Air Force, probably enough has been said to show how heavily our national defense depends on the development of improved materials.

*In a talk before the Western Mining Conference in Denver on Feb. 9, 1957, Brig. Gen. Clyde H. Mitchell, deputy director of production of the Air Materiel Command, said that "the new generation of combat aircraft — our fighters and bombers — is completely reversing the proportions of light metals to the hard metals, with 70 to 75% of steels of various kinds in new fighters as contrasted to previous usage of 15 to 20%, and our operating inventory must be replaced with these superior aircraft within the next 10 years."

The Surface Metallurgy of Protective Coatings

*By CHARLES L. FAUST**

Protective alloy coatings for high-temperature service are made by plating alternate layers of the metals and then alloying by a diffusion heat treatment. Results are often affected by the surface condition of the basis metal. Rapid diffusion alloying of basis metal and coating and diffusion through the coating may sometimes be stopped by an intermediate barrier layer or thin plate of a third, slowly diffusing metal. (L15, L17, L22, N1h, 2-12)

IN MANY SITUATIONS where a metal structure is subjected to aerodynamic heating, the temperature at the outer surfaces may rise rapidly but for so short a time that the surface is affected far more seriously than the bulk of the metal – even of a metal skin. Hence the interest in composite materials wherein the outer layer would be chosen primarily to protect the stress-carrying metal underneath.

Such considerations have led to a careful scrutiny of the various methods of applying coatings of metals, metallic alloys or cermets, the nature of the coatings as related to the method of deposition, and the effect of the coating process on the basis metal. All these build up into the conception that the properties of the *composite* are of prime importance. When this matter is looked into we find that it depends to a striking extent on the interfacial zone between basis metal and coating. It is this aspect of the matter which will now be briefly discussed.

Surface Metallurgy

The interfacial zone between the basis metal and its protective coating can be responsible for the success or failure of the composite item. Adherence of coatings is, of course, important under the conditions of service. Also, the bond strength is a property that encompasses more than adherence and has much more significance for coated materials at high temperatures than at atmospheric.

The interfacial zone has three parts:

1. The outermost surface of the basis metal viewed as a "skin", the significant thickness of which may be from a few Ångstroms to as much as 0.010 in.

2. The first layer of the coating which may involve thickness of a few Ångstroms to as much as 0.002 in.

3. The alloy formed by diffusion of coating and basis metal from a few Ångstroms to 0.02 in. or more in thickness.

*Chief, Electrochemical Engineering Div., Battelle Memorial Institute, Columbus, Ohio. This article is a portion of a paper entitled "Protective Metal Coatings" presented before the Conference on Heat Tolerant Metals for Aerodynamic Applications, held in Alburquerque, N.M., late in January and sponsored by the Albuquerque and Los Alamos Chapters ⊖, and the University of New Mexico.

This three-part interfacial zone and the metallic coating comprise a subject which can be called Surface Metallurgy.

The contribution of Item 1 to over-all performance is intimately tied in with the history of the basis metal and particularly with the kind of operations which have been performed on its surface to prepare it for the coating operation. Item 2 is considered distinct from the coating proper, because the structure and properties of the initial layers of coating can differ significantly due to the interacting influences of the nature of the basis metal's surface and of the method of applying the coating.

Item 3, diffusion alloy formation, will provide the compositions predicted by the appropriate phase diagrams for the metals involved, modified by such effects as time and temperature.

The quantitative status of each of the three items will vary somewhat as to coating methods and as to performance in service. Yet, the general effects give guidance for choosing protective coatings, show areas where correct technology and excellent workmanship are imperative and give a basis for troubleshooting and determining the causes for poor perforance – all regardless of the kind of composite system and of the method for applying the coating.

Surface Preparation

First of all, the basis metal must be cleaned. Three types of cleanliness are involved. Each affects the integrity of a coating, its adherence and the bond strength (strength of the intermediate zone).

Fig. 1 – Appearance of a 3 to 5-Rms. Micro-Inch Finish as Seen at 7500 Diameters. Note the folds and clods of loose metal, as would be seen on a "plowed field". (Courtesy C. L. Faust in Electroplating Engineering Handbook)

Fig. 2 – Cross Section of Buffed Metal Surface Showing the Severe Surface Distortion. 200×. (Courtesy A. T. Steer)

Physical and Chemical Cleanliness – The importance of these two conditions has long been recognized. Consequently, techniques are well known for removing oils, greases, and other soils so as to provide physical cleanliness. Likewise, pickling, chemical dipping, and blasting methods are well established for removing oxides, scale, and salts derived from the basis metal so as to make it chemically clean.

Mechanical Cleanliness – Too little has been said and done about this important surface condition relative to its effect on the mechanical properties of the surface of the basis metal and to its influence on applied coatings. Mechanical operations distort, strain, tear and smear the surface; it is weak and has the appearance of a plowed field even for a smoothness of 3 to 5 micro-inches (root mean square). For example, the damaged surface of a 100,000-psi. steel has a tensile strength of only 35,000 psi. after turning in a lathe. This weak skin is the Achilles heel of a composite comprising the steel and a coating of 90,000 psi. tensile strength. Even fine abrasive finishing gives the plowed-field appearance shown in Fig. 1. An attempt to smooth such a surface by buffing can give a small-value micro-inch finish (less than 0.1 r.m.s.) but not without distortion such as that shown in Fig. 2. The physical state of the surface directly influences the structure of a coating applied by electroplating as shown in Fig. 3.

These situations in the interfacial zone are especially significant for electrodeposited coatings, and also need to be recognized when using such other methods as vacuum exaporation, vapor-phase deposition, chemical reduction, spraying, and hotdipping. Unfortunately, specific quantitative information is limited and scattered. Thus, a designer for heat tolerance in high-temperature service may have to get his own data.

Effect of High Temperature

Diffusion Alloy Zone – The formation of an alloy zone can be a blessing or a detriment, according to circumstances. Thus, a nickel coating on zirconium needs interfacial alloying for good adherence. Four hours at 1100° F. does not produce a bond; 4 hr. at 1200 or 45 min. at 1300 produces a bond of 50,000 psi. strength; longer times will weaken the bond. Not only that, but a surface hydride is formed on zirconium exposed to aqueous and electroplating baths, and baking at 400° F. or storage for several weeks is necessary in order to avoid blistering when a coating on zirconium is heated to 1100° F. or higher. For protection, metallic coatings usually must exceed 0.002 in., and a nickel coating that thick tends to blister during diffusion-alloy bonding, possibly because of difference in thermal expansion. To avoid this, 0.0005 in. of nickel can be diffusion-bonded, after which additional nickel or some other coating can be electrodeposited, or applied by extrusion, cladding or roll cladding. However, bond strength is seriously impaired by time at high temperature, dropping, for example to 5000 psi. after 4 hr. at 1500° F. Iron can be used as an intermediate coating for diffusion alloying and a bonding intermediate. Alloying with zirconium takes place in 5 to 15 min. at 1500° F.

Fig. 3 – Structure of Copper Electroplate Deposited Under the Same Conditions on Each of Three Different Conditions of Basis Metal Surface. 500×. Top: Effect of a deep scratch. Center: Electropolished surface. Bottom: Mechanically buffed surface

Studies of chromizing have shown that the rate of chromium diffusion in steel is influenced by the carbon content up to 0.6%, beyond which the carbon content has little influence. The diffusion rate is larger the lower the carbon content. Hence, surface decarburization (or the presence of strong carbide-forming alloying elements such as titanium, columbium and vanadium) prevents the formation of chromium carbides which act as a diffusion barrier. The chromium diffusion layers are harder as carbon content increases. (On cast iron the surface is hard enough to cut glass.) Chromized mild steel can be rolled, bent, pressed, heat treated and quenched without damage to the coating – a testimony to the good properties of the diffusion alloy. Such surfaces can also be brazed, silver soldered and welded by normal methods.

The chromium content varies from 35 to 50% and more in the outer layer to about 13% at about 0.004-in. depth, which corresponds to the general thickness of coating. The average chromium content of the surface alloy is about 25% for application temperatures in the range of 1900 to 2100° F.

Recrystallization at Finished Surface – Sometimes the strained skin recrystallizes at lower temperature than the bulk of the basis metal, and consequently has a lowered stress-rupture strength. The amount of strain at the surface of the basis metal also affects the speed of formation and the nature of the diffusion alloy which forms. Recrystallization of the skin might be relied upon to regenerate good mechanical properties before a coating is applied or during a high-temperature "break-in" treatment. Yet, recrystallization does not always rectify the surface condition. Figure 4 shows that prolonged heating has recrystallized a surface-damaged skin, but has not reabsorbed it in the bulk structure, possibly because of embedded buffing compound such as shown by Fig. 5.

Such instances as those just cited are potential causes for premature failures in composites in which the basis metal is supposedly protected by a metallic coating. The lack of any specifi-

Cost of Nuclear Developments

The 21st Semiannual Report of the U.S. Atomic Energy Commission to the Congress dated Jan. 30, 1957 is notable for a 150-p. staff report on "Radiation Safety in Atomic Energy Activities". It also contains the following data on its various operations:

Costs of operations for fiscal year ending June 30, 1956 were

	$ IN MILLIONS	% OF TOTAL
Source materials	281	17.5
Production	729	45.3
Weapons	281	17.5
Reactor development	177	11.0
Research	81	5.0
Administrative	59	3.7
TOTAL	$1,608	100.0%

Source materials includes principally the mining and concentration of uranium ores or purchase of foreign supply. Eleven privately owned mills and one governmental mill, with daily capacity of 8960 tons of ore, produced 3400 tons of U_3O_8 concentrate in the last half of 1956. Eight more mills are under construction. It was officially stated on Feb. 9, 1957 that "uranium supply from existing contracts [including foreign] and estimated increased domestic production will provide for the projected requirement for the next 10 years." Domestic ore reserves carry from 0.20 to 0.35% U_3O_8.

Production of special nuclear materials includes feed materials (highly purified uranium metal or UF_6) made in eight plants costing $220.8 million; the production of uranium enriched in U^{235} in three diffusion plants costing $2,284.2 millions (Oak Ridge, Tenn., Paducah, Ky., and Portsmouth, Ohio); the production of "plutonium and other reactor products" at Hanford, Idaho, and Savannah River, S.C., the two plants costing $1,511 million; and heavy water at Dana, Ind., and Savannah River, the two plants costing $264 million.

Costs of product might be assumed to be roughly proportional to prices set for sale of quite limited amounts to cooperating foreign governments:

Refined uranium metal (natural)	$40.50 per kg.
Uranium enriched to 1% U^{235}	75.75 per kg.
Uranium enriched to 10% U^{235}	1,529.00 per kg.
Uranium enriched to 90% U^{235}	15,361.00 per kg.
Plutonium (buy-back price)	$12.00 per g.
Uranium-233	$15.00 per g.
Heavy water	$28.00 per lb.

Weapons include construction and storage of war heads, test firings, and research on all military applications. No information is available to the general public. The costs noted in the tabulation include operation of Los Alamos (N.M.) Scientific Laboratory, the Sandia Corp.'s activities at Albuquerque, N.M., the Radiation Laboratory at Livermore, Calif., and several ordnance plants.

Reactor development costs are increasing sharply, fiscal 1956 being up 48% over fiscal 1955.

Of the total, $49,600,000 was spent on the air-

cation for mechanical cleanliness also is responsible for many discrepancies in attempts to repeat results reported by others.

Intermediate Coatings

On Molybdenum – Molybdenum and its high alloys have such good mechanical properties at high temperature that many efforts have been made to correct its unfortunate tendency to oxidize or otherwise waste away at a very rapid rate. Coatings of chromium, nickel and cobalt rapidly diffuse into the basis metal. A nickel-molybdenum diffusion alloy zone 0.006 in., a cobalt-molybdenum zone 0.002 in., and a chromium-molybdenum zone 0.001 in. formed during 100 hr. at 2000° F. The molybdenum diffuses intergranularly about five times as fast as the alloy zone forms. Because molybdenum diffuses so rapidly through a chromium coating and the nickel-chromium diffusion alloy coating, a molybdenum rod lost over 8% of its initial weight during 100 hr. in air at 1800° F. (At the outer surface the molybdenum combined with oxygen in the air and the oxide volatilized.) Tests showed no porosity in the coating.

A chromium-nickel alloy, prepared by plating alternate layers of the two metals and then heating for mutual diffusion, gave good protection for molybdenum. However, the high temperature required for diffusion would prevent its use on most other metals.

A chromium-gold-chromium intermediate

craft reactors program described in 19 lines in this semi-annual report. A laboratory model of "a turbojet engine was powered exclusively by heat from an experimental reactor" and additional test and laboratory facilities constructed at two sites. This project has cost $138,000,000, fiscal 1950 to 1956, inclusive.

Naval propulsion reactors cost $40,900,000 (total of $273,300,000 in fiscal 1948 to 1956 inclusive). The submarine Nautilus has operated satisfactorily for nearly two years, steaming over 50,000 miles, submerged for more than half that distance. Its land-based prototype (pressurized water) in Idaho, still being operated, worked at 100% full power for 66 days in one test.

The submarine Seawolf's propulsion plant (sodium cooled) developed operating troubles, as described in *Metal Progress* in March. [The land-based prototype located at West Milton, N.Y., is to be dismantled, but the steel housing retained for future prototype power plants.]

Three other naval units are briefly described as under design or construction – an advanced version of the Seawolf, a propulsion plant for a small submarine, and one of 20,000 shaft hp. for a large ship.

Reactors for the Army include a "package power reactor", almost completed, and designed to produce 1825 kw., and a smaller one of 200-kw. capacity. Anticipated total expenditures on these amount to $6,300,000. [All the above power reactors for the military branches were briefly described in *Metal Progress*, October 1956, p. 110.]

Research and development work on experimental power reactors (nonmilitary) cost $42,200,000 in fiscal 1956 (and a total of $108,700,000 since 1948). Well over 100 reactor concepts have been explored in the Commission's laboratories. Data on 25 of the principal reactors are contained in a tabulation in *Metal Progress*, September 1956, p. 96-B. Excluding the 43 military reactors and 12 power reactors being built by private industry, the complete listing as of Dec. 31, 1956 totals 153, subdivided as follows:

	Operating	Building	Planned
Research reactors	27	11	26
Critical experiments	24	10	7
Production reactors	13		5
Civilian power experiments	4	9	
Completed and dismantled	17		
Totals	85	30	38

Investment in the six major national laboratories at the end of fiscal 1956 totaled $443,112,000. The amount of money spent for research, excluding depreciation, is subdivided as follows:

Chemistry	$16,925,000
Metallurgy	4,826,000
Physics	24,095,000
Cancer	3,109,000
Biology	10,302,000
Medicine	8,776,000
Biophysics	3,159,000

About 800 research contracts were placed with universities and independent laboratories at a cost of $18,600,000 during fiscal 1956.

plate prevented outward diffusion of molybdenum; the structure of such a composite surface is shown in Fig. 6.

Further evidence of the benefit of a barrier layer in a coating is seen in the use of a thin nickel plate for preventing stress-corrosion cracking by cadmium plate on low-alloy steel parts for jet engines at temperatures up to 1000° F. Cadmium coating protects the steel up to about 500° F. Danger of intergranular attack of the highly stressed steel begins where cadmium melts – namely, 611° F.

If a metal used for coating has a melting point below the temperature of service, or forms a eutectic of low melting point with the basis metal, it can still be useful if alloyed to raise the melting point. Otherwise, such coatings will need an intermediate barrier to prevent intergranular attack on the basis metal.

Cladding – Diffusion alloying can be a great help, as in cladding steel with a corrosion or oxidation resisting coating. For example, sheets of stainless steel and Inconel are nickel plated for diffusion bonding to steel during hot rolling. The cladding resists oxidation at high temperatures, and is well and permanently bonded to form a composite that can be sheared, cut, bent, welded, and the like. Further diffusion alloying at high temperature will be no detriment.

Because of its strength and oxidation resistance up to 2100° F., Inconel is a promising material for coatings. Inconel coatings on

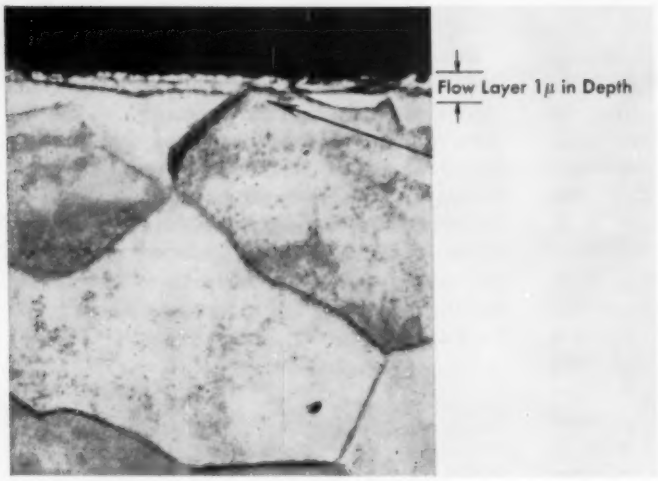


Fig. 4 — Flowed Surface Skin Recrystallized (but not the Structure of the Bulk Metal) After 300 Hr. at 935° F. 3000×. (Courtesy A. T. Steer)

Fig. 5 — Cross Section of Polished Surface Showing Embedded Abrasive. Unetched. 3000×. (Courtesy A. T. Steer)

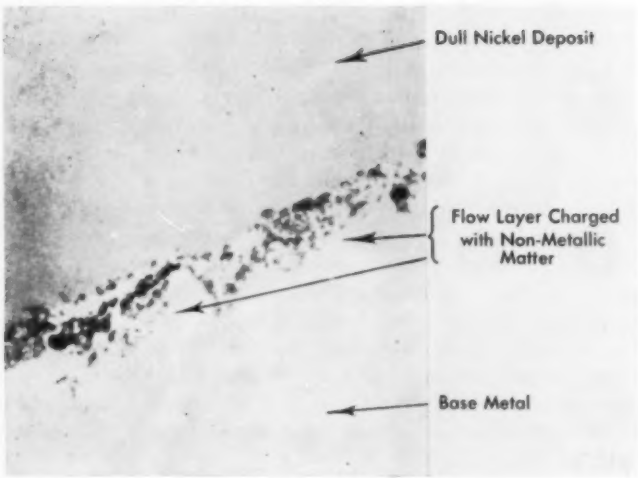
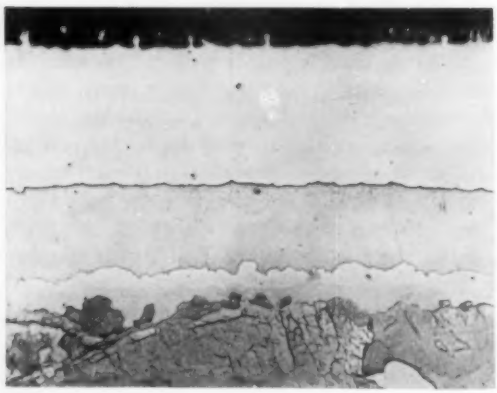


Fig. 6 — Chromium-Gold-Chromium Surface Electroplated on Molybdenum and Heated 100 Hr. at 1800° F. in Argon. 400×. Layers from top to bottom are chromium (180 Knoop hardness), gold-chromium alloy (199 hard), molybdenum-chromium alloy (470 hard) and molybdenum, the basis metal, 230 Knoop hard. (Courtesy Messrs. Safranek and Schaer)



molybdenum at high temperatures remained intact when hit with shot from an air gun — a test of impact resistance.

From this very brief review of available information it may be concluded that metallic coatings will be very useful for providing high-temperature surface protection for metals which have the necessary bulk properties but not surface stability to tolerate rapid and intense heating. Sound composite parts can be provided for engineering use when surface metallurgy is correctly considered and the strength and properties of the surface alloys formed by diffusion are known to be satisfactory. When the individual coatings and basis metals have suitable properties, but the diffusion alloy formed at the interface between them does not, the necessity for a proper barrier coating is indicated.

Explosions of Molten Aluminum in Water – Cause and Prevention

*By GEORGE LONG**

Violent explosions occur when a thin layer of water is trapped under a sudden rush of molten metal, and they can be avoided by greasing or painting the bottom of the water container. (A7p, C5; Al, 14-10)

ACCIDENTAL SPILLING of molten materials into water or onto wet surfaces is a serious industrial hazard. In the smelting of copper sulphide ores, for example, it has long been customary to granulate the slag for easy disposal as a slurry, but small amounts of molten matte (mixed metal sulphides) will act like dynamite when accidentally getting into the launders. Hot copper striking damp ground is likely to be blown all over the premises by the expanding steam. Witness also the following account taken from the files of the Manufacturers Mutual Fire Insurance Co.:

"After tapping steel from a furnace, the slag was being drained into a slag pot in the pit. One of the chains supporting the pot parted, allowing the contents to drain into the pit. The pit bottom was wet and an explosion followed. About 17,000 sq.ft. of corrugated iron roofing and 3000 sq.ft. of steel window sash were blown off the building."

However, the chance of accident is not limited to reactive compounds or trapped steam. Molten steel dropped into a considerable body of water can explode, as proved by another citation from the same insurance company's files:

"A 25,000-lb. charge of chromium steel was being reladled (poured from the furnace into the ladle, and then back into the furnace) when the craneman tipped the ladle accidentally. Molten steel fell into an open trough of water. The resultant explosion was heard three miles away. One bay of the building was completely stripped of sheeting and window sash and three other bays were partly stripped."

Such industrial hazards have been increased by improved ingot casting methods introduced in recent years which cool the metal very rapidly with water, and where large quantities of molten metal and water are in close proximity. These casting methods are used extensively in the aluminum industry, and several moderate-to-severe explosions have occurred. Therefore, an

*Physical Chemistry Div., Alcoa Research Laboratories, New Kensington, Pa. The author wishes to acknowledge the guidance of W. T. Ennor and P. T. Stroup, assistant directors of research, and helpful criticism of the manuscript by L. M. Foster.

Fig. 1 – Explosion Test Station. Cell has 2-ft. reinforced concrete walls; melting furnace and other auxiliaries are located in small building at rear made of concrete blocks

Fig. 2 – Dugout and Mirrors at Observation Station

extensive investigation by the Alcoa Research Laboratories was directed toward determining the conditions that produce explosions when molten aluminum enters a body of water, and finding ways to prevent them.

Equipment and Procedure

Tests were conducted within a wood-faced sand enclosure until an explosion of sufficient violence occurred to move the 24-in. walls. A steel reinforced concrete enclosure was then built and used for the remainder of the tests. A concrete block building at the rear (Fig. 1) housed the necessary auxiliary equipment, such as a metal melting furnace, a crucible preheating furnace and water containers. An observation post (Fig. 2) 100 ft. away was provided with mirrors so a protected observer could view the action.

The procedure consisted of suspending a crucible containing a weighed amount – usually 50 lb. – of molten, commercially pure aluminum above a container partially filled with water. The metal was poured into the preheated crucible, the crucible taken to the test cell and the test set up. When the metal had cooled to the desired temperature, a remotely controlled tripping mechanism lifted the plunger and stopper, and the metal flowed through the tap hole in the bottom of the crucible into the water. The general arrangement is shown in Fig. 3.

The water containers were welded of 3/16-in. mild steel plate, and ranged in size from 6½ to 48 in. square, and 12 to 36 in. deep. Concrete containers were also used in a few of the tests.

The explosions were characterized by a violent bursting action, closely followed by a loud noise and a shock wave. Quantities of finely divided aluminum were formed along with a white cloud of smoke, probably aluminum oxide. All but the mildest explosions broke the steel water containers at the welded joints and frequently hurled the pieces several hundred feet. The concrete containers were also shattered into small pieces. Sometimes the explosions broke the pouring crucible as well.

The results were similar to the detonation of explosives. They appeared to occur very rapidly after pouring the metal had started. No one of several observers could discern any interval

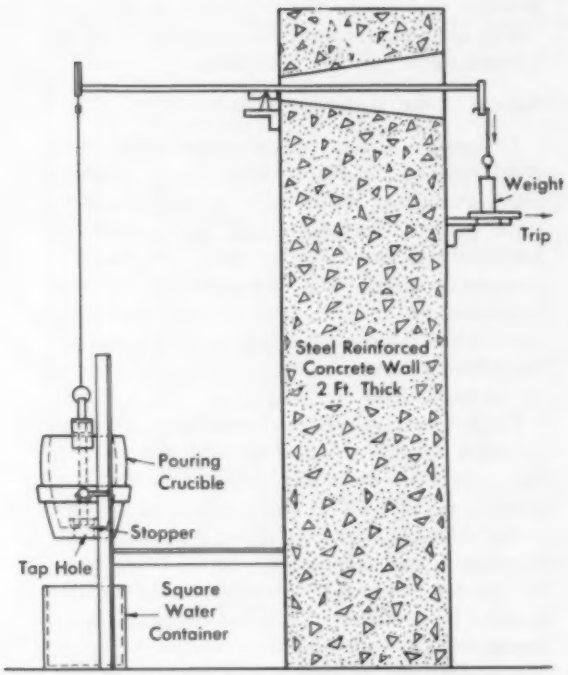


Fig. 3 – Sketch of Device for Inducing Explosions When Teeming Hot Aluminum Into Water

between the time the tripping mechanism was actuated and the explosion, which meant that the explosion occurred before all the metal had reached the water. One test was conducted at night, without lights. Three observers agreed that they could not detect any flash or fire during the explosion or immediately after except for a glow of red-hot metal.

The criterion for evaluating the results was simply whether there was or was not an explosion. No attempt was made to measure the relative violence (except in two tests) since *any* explosion was considered hazardous. An additional hazard would come from molten metal blown out of the water container without bursting the vessel – an action obviously much milder than an explosion, but since molten metal was often spattered over a considerable area it could have caused severe burns to anyone in the vicinity.

Results With Aluminum

A total of 880 tests were carried out to study the various factors that might affect the explosions. Unless otherwise noted, all tests involved the sudden discharge of 50 lb. of commercially pure, molten aluminum through a 3¼-in. diameter hole into a clean degreased steel container partially filled with water at 55 to 78° F. The steel containers were degreased by heating to a dull red, cooling and rinsing with water.

Metal Stream Quantity – The ability to produce an explosion was found to depend on the size of the molten metal stream that entered the water. There were no explosions when the metal was discharged through ¾, 1½ or 2½-in. diameter holes. Increasing the hole size to 2¾, 3¼ and 4 in. resulted in explosions.

With any given size tap hole, a certain amount of metal was required to produce an explosion. Additional amounts did not seem to increase its violence, possibly because the crucible frequently was shattered before all the metal drained out. When the metal stream was smaller than 2¾ in. in diameter and no explosion occurred there was no evidence that more than the usual quantity (50 lb.) would cause an explosion.

The exact amount of metal needed for an explosion was not accurately determined, but we did find that 10 lb. of aluminum at 750° C. (1380° F.) flowing in a stream of 2¾ in. diameter would explode with sufficient violence to burst a steel water container.

The *distance* the metal dropped before reaching the bottom of the water container was varied to determine its effect. Explosions occurred when this distance of metal drop was 18 in., 3 and 4 ft., but no explosions occurred in 19 tests using a 10-ft. drop. This is significant, because the water and metal are at considerable distances apart in many industrial installations where metal-water accidents are possible. The most probable explanation for these experimental results is that the metal stream breaks up during a long vertical fall.

This supposition was checked by placing a steel grid with 1-in. square openings over the top of the water container. No explosions were obtained in 13 tests when the metal stream was dropped 18 in. into the water. Tests conducted under the same conditions without the iron grid resulted in explosions.

Water Depth and Temperature – The metal temperature and the depth of the water pool were found to be dependent on each other. As the depth was increased, progressively higher metal temperatures were required. With a 3 or 6-in. water pool explosions occurred at a metal temperature of 670° C. (1240° F.). When the water depth was increased to 10 in., no explosion occurred at 670° C. but did occur

at 750° C. (1380° F.). No explosions occurred in water 20 in. deep and 750° C. metal, or at 30 in. deep and 900° C. (1650° F.) metal. No hotter metal was tried.

No explosions of sufficient violence to break the water container were encountered in tests when the water depth was 2 in. or less. Instead, molten metal was blown out of the container, and this spattered molten metal over a considerable area and must be recognized as a serious hazard.

Explosions of similar intensity were encountered in square water containers 6½, 12, 17 and 24 in. on a side. When the size was increased to a 48-in. square, a milder explosion occurred that did not break the container.

Lateral dimensions of the pool are evidently of less importance than its depth, but there is an indication that, for the same metal quantity, a large pool decreases the hazard of explosion.

As shown by 34 tests, water temperature has an important effect. In all of these, 50 lb. of 1100 alloy (old designation 2 S, 97% Al min.) at 750° C. (1380° F.) was discharged through a 3¼-in. hole 18 in. into either 6 or 10 in. of water in a 12-in. square steel container. Explosions always occurred in the 18 tests when the water was in the range of 32 to 122° F., but did not occur with warmer water (140 to 212° F.).

Effect of Additives in Water

Since soluble oils, wetting agents and salt are known to influence the rate of heat transfer during metal quenching, this was investigated and it was found that soluble oils and wetting agents can prevent explosions while salt promotes them. In these tests the other conditions – metal, temperature, and so on – were the same as noted just above except that there was always 6 in. of water in the container.

The addition of 0.5% soluble oil ("Fiske No. 101" or "Solvac P 1535" oil) prevented explosions in all the tests. When the amount was decreased to 0.01%, explosions did not occur when the solution temperature was in the range of 68 to 185° F., but did occur in cold water at 32° F.

Aerosol OT wetting agent exerted the same effect. When only 0.01% was used, explosions did not occur at temperatures of 64 and 158° F., but did occur at 32° F.

Sodium chloride had the opposite effect. A 15% NaCl solution permitted explosions at temperatures of 72 and 172° F., whereas none resulted in clear water at 140° F. and higher.

Although soluble oils and wetting agents thus prevent explosions, they are not of practical use in aluminum casting because they exert an adverse effect on ingot quenching.

Nature of the Water Container

Concrete – A total of 32 experiments were conducted to determine what effect concrete water containers would have on the explosions, since concrete surfaces would be encountered frequently in industrial locations. Similar explosions occurred. The various factors affecting explosions in steel buckets exerted the same effect when the container was made of concrete. No difference was found between concrete cured for 48 hr. and for 30 days.

Oxide Coatings – Experiments using a 1½-in. diameter stream of metal showed that coating the surface of the water container with lime, gypsum or rust led to explosions that did not occur under similar conditions with uncoated, degreased steel containers. As in other tests, the tendency toward explosions could be decreased by lowering the metal temperature or increasing the water depth.

A heavy layer of aluminum hydroxide or iron hydroxide sludge on the bottom of the container was also found to favor explosions.

Good Effect of Grease, Oil and Paint

The phenomenon under study was extremely sensitive to very small traces of grease and oil. They had to be carefully removed from the steel plates from which the water containers were fabricated before explosions could be obtained consistently. When grease or oil was intentionally placed on the bottom surface, explosions never occurred.

In more than 50 tests "Shell Dolium No. 2" grease or "Sun Cerco XXX" heavy oil was spread on the bottom and sides of the water containers. No explosion ever occurred over a wide range of metal temperatures – 700 to 800° C. (1290 to 1470° F.) – and water depths from 1½ to 10 in. It made no difference whether the container was steel or concrete.

When the bottom of the water container was coated with grease leaving the sides bare, no explosions occurred. When the sides of the container were coated with grease leaving the bottom bare, explosions did occur.

The slight solubility, if any, of the grease in water was not sufficient to explain this. In one test, a ball of "Shell Dolium No. 2" grease was suspended in the container of water for 30 min. and removed prior to testing. An

Table I – Effect of Paints on Aluminum-Water Explosions*

No. of Tests	Trade Name of Paint	Metal	Water Depth	Container and Size	Result
1	Rustoleum H-7	10 lb.	4 in.	Steel, 6.5 in.	No explosion
3	Rustoleum H-7	10	5	Steel, 6.5	No explosions
1	Rustoleum H-7	50	3	Steel, 12	No explosion
3	Rustoleum H-7	50	6	Steel, 12	No explosions
1	Rustoleum H-7	50	10	Steel, 12	No explosion
1	Rustoleum No. 769	10	4	Steel, 6.5	No explosion
4	Rustoleum No. 769	10	5	Steel, 6.5	No explosions
1	Rustoleum No. 769	50	3	Steel, 12	No explosion
3	Rustoleum No. 769	50	6	Steel, 12	No explosions
1	Rustoleum No. 769	50	10	Steel, 12	No explosion
1	Bituminous Black	10	4	Steel, 6.5	No explosion
4	Bituminous Black	10	5	Steel, 6.5	No explosions
1	Bituminous Black	50	3	Steel, 6.5	No explosion
3	Bituminous Black	50	6	Steel, 12	No explosions
1	Bituminous Black	50	10	Steel, 12	No explosion
2	Socony Sova Kote No. 601	50	6	Steel, 12	No explosions
2	Black Mastic	50	6	Steel, 12	No explosions
3	VF 1637 Varnish pigmented with Alcoa 205 Paste	50	6	Steel, 12	2 explosions
1	Amercoat No. 33 Al. Paint	50	6	Steel, 12	No explosion
2	Bituminous Black	50	6	Concrete, 12	No explosions
2	Black Asphaltum	50	3	Concrete, 12	No explosions
3	Black Asphaltum	50	6	Concrete, 12	No explosions
2	Black Asphaltum	50	10	Concrete, 12	No explosions

*1100 alloy at 750° C. (1380° F.), discharged through a 3½-in. hole from a height of 18 in. into 12 in. of water.

explosion occurred on discharging molten metal into this container of water.

Oil or kerosene poured over a lime-coated container prevented an explosion under circumstances which otherwise would have led to one.

This effect of grease and oil pointed to a practical method for eliminating explosions.

Since paint has numerous advantages over a grease coating, more than 50 tests were run on many industrial paints under a wide variety of experimental conditions. The results are shown in Table I.

Explosions were never obtained in tests when the container surface was painted with "Rustoleum H-7", "Rustoleum No. 769", "Bituminous Black", black asphaltum, "Socony Sova Kote No. 601" and black mastic paints. However, an exception was noted with aluminum paint; in four tests two explosions occurred.

No explosions were obtained when the container surface was painted with unpigmented phenolic resin-type vehicles. Likewise, there were no explosions when a number of other unpigmented vehicles were used. In these tests conditions were such as to insure an explosion in water in a clean, bare container: 50 lb. of commercially pure aluminum at 750° C. falling 18 in. in a 3¼-in. stream into 6 in. of water. No explosions were produced in duplicate tests in steel containers coated with the following vehicles: Linseed oil, tung oil, ester gum in mineral spirits, vinylite resin, n-proxyl methacrylate, spar varnish, or Bakelite's "VF 1637" varnish.

Coatings of hydrated chemical compounds on top of the paint coating tended to destroy the effectiveness of the paint. In one test where a lime coating was placed over a Rustoleum H-7 paint coating, an explosion occurred. In a duplicate test, pouring oil over the painted and limed container prevented the explosion; thus it appears that it is the top coat that rules.

Molten Salt and Water

A molten mixture of equal molecular amounts of sodium chloride and potassium chloride was also poured into water as above, and explosions always occurred, somewhat less violent than the aluminum and water explosions. The relative violence was measured twice with a microphone pickup and cathode-ray oscilloscope. An aluminum and water explosion of average intensity gave readings about one and one half times as high as a salt explosion.

Three major differences were found: The salt explosion was not prevented by a 20-in. depth of water, by grease coatings on the water container, or by soluble oil in the water.

The Mechanism of Metal Explosions

The experiments were conducted under conditions that simulated sudden accidental pouring of molten aluminum into a pool of water. (A limited number of tests with molten magnesium* suggest that the results may apply to other molten metals.) This is not the only possible kind of explosion; for example, a "boiler explosion" type of accident is possible in a water jacket.

H. M. Higgins has recently reported on the reaction of some other molten metals and water† specifically zirconium, "Zircaloy-2", uranium, uranium-molybdenum alloy, aluminum, aluminum-lithium alloy and magnesium. He found that as long as the molten metals remained as comparatively large globules, the reaction ceased after some surface scale had formed. When the molten metals were dispersed in water in any way, zirconium, "Zircalloy-2", Al-Li alloy and magnesium underwent a violent reaction. Aluminum did not. Uranium and U-Mo alloy were not tested in this way.

In order to produce an aluminum and water explosion of the type studied in this test program, three requirements apparently must be fulfilled:

1. Molten metal in considerable quantity must penetrate to the *bottom surface* of the water container.

2. A triggering action of some kind must take place on this bottom surface when it is covered by the molten metal.

3. Water depth, temperature and composition must be proper for the rapid transfer of a large quantity of heat from the metal to the water.

It is believed that the triggering action is a minor explosion due to the sudden conversion to steam of a very thin layer of water trapped below the incoming metal. In shallow water this preliminary explosion merely blows molten metal and water out of the container. In deeper pools the incoming metal is dispersed in particles whose small size and rapid upward rate of movement prevent the formation of any vapor blanket and the very sudden transfer of heat forms steam fast enough to cause a serious explosion.

When the experiments are reviewed in the light of this three-part mechanism, all of the results fall into line:

With deep water, small amounts of metal, or metal dispersed into many small streams, any explosion is prevented because a sufficient amount of molten metal does not reach the bottom of the water container.

With grease, oil or paint on the container bottom, the explosion is prevented because the thin layer of water required for the preliminary triggering explosion is not trapped beneath the molten metal.

With hot water or with water containing small amounts of soluble oil or "Aerosol", the tendency toward the formation of a vapor blanket around the metal particles is increased to such an extent that the rapid transfer of heat necessary for the explosion never occurs. Explosions do occur when vapor blanket formation is hindered by a salt solution.

There has naturally been much consideration of the possibility that the exothermic reaction

$$2Al + 3H_2O \rightarrow Al_2O_3 + 3H_2$$

enters into the explosion mechanism. No absolute proof can be given for the belief that, if such a reaction is involved, it plays a very minor part. Considerable strong evidence can be mentioned: There is no visible flash and never more than a slight cloud of aluminum oxide, as might be expected when hot aluminum is very finely dispersed in air. Very similar explosions have occurred with nonmetals such as molten chlorides. Since hot water or 0.5% soluble oil stopped the explosion, and since the coating on the container bottom is so important, we find it difficult if not impossible to reconcile these facts with the supposed chemical reaction.

There is no evidence whatever of a hydrogen explosion, a thermit reaction with iron oxide, or of mechanical restraint of expanding steam by solidifying metal.

Preventing the Explosion – Since this experimental investigation, the Aluminum Co. of America has found the use of grease or paint coatings effective on a plant scale in situations where large quantities of molten aluminum might accidentally discharge into water. No explosions have occurred during this period although, on occasion, large quantities of molten metal have been accidentally spilled into water. Whenever possible, also, a deep pool of water has been provided.

*A total of 19 tests using molten magnesium under the same experimental conditions showed that the magnesium-water explosion was analogous to the aluminum-water explosion except for persistent fires following the former. Magnesium explosions were prevented by the same grease and paint treatments that prevented aluminum explosions.

†"A Study of the Reaction of Metal and Water", Document AECD-3664, Atomic Energy Commission, April 15, 1955.

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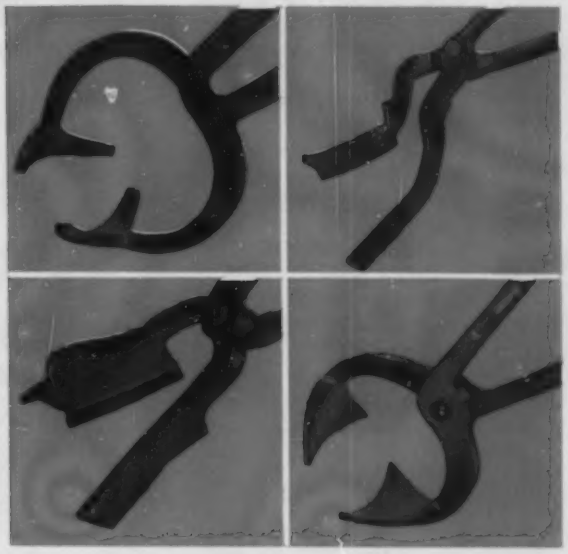

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Personal Mention

Stewart G. Fletcher

Robert Maddin

STEWART G. FLETCHER has been promoted to the position of vice-president, metallurgy, at Latrobe Steel Co., Latrobe, Pa. In his new post, Dr. Fletcher will be responsible for all metallurgical activities concerned with the products manufactured by Latrobe Steel Co.

Dr. Fletcher has been connected with research and development work on toolsteels and allied materials for over 15 years. Following graduation with a bachelor's degree in metallurgical engineering from Carnegie Institute of Technology, he spent a brief time with the Aluminum Research Laboratories. Then in 1939 he entered the graduate school of Massachusetts Institute of Technology on a teaching fellowship, and later received his doctor of science degree in metallurgy.

During the Second World War, Dr. Fletcher was engaged in research on heat treatment at M.I.T. and as a result of these studies he was twice (in 1945 and 1949) awarded the Howe Medal by the American Society for Metals.

In 1945 he became associated with Latrobe Steel Co. as chief research metallurgist and two years later rose to chief metallurgist; last year he became director of metallurgy, holding this post until his recent appointment.

ROBERT MADDIN, professor of metallurgy at University of Pennsylvania, is now director of the school of metallurgical engineering. Well-known for his research work and contributions to technical literature in the metallurgical field, Dr. Maddin became a faculty member at Pennsylvania in July 1955 and a few months later was named acting director.

After receiving his B.S. in metallurgical engineering from Purdue University in 1942, his education was interrupted by three years active service with the U.S. Air Force. He later entered Yale University's graduate school, receiving his doctorate in engineering in 1948. During this period he was an instructor in chemistry at New Haven Junior College. In addition, Dr. Maddin has taught at Johns Hopkins University and served as visiting professor at Massachusetts Institute of Technology and the University of Birmingham, England. He has also found time to serve as consultant to nearly a score of firms.

For the past eight years, he has been studying the deformation and recrystallization of metals for the U.S. Office of Naval Research, and last year was awarded a research contract with the U.S. Atomic Energy Commission for work on the effect of plastic stresses on diffusion.

Active in many technical groups, Dr. Maddin is chairman of the 1957 Seminar Committee and a member of several committees of the A.I.M.E.

E. G. de Coriolis was named "Engineer of the Year for 1957" by the Toledo Technical Council at the Sixth Annual Engineers' Week Banquet in Toledo early this year. Mr. de Coriolis has been associated with the Surface Combustion Corp. for over 30 years as director of research and development.

Bernard N. Ames has become a member of the board of directors of the John B. Salterini Co., Inc., New York. The new director is president of Columbian Bronze Corp., Freeport, N.Y., and has also been affiliated with Phelps Dodge Copper Products and the New York Naval Shipyard, where he served as head of the casting development and foundry practices sections of materials laboratory.

Elwood Eutermoser has been assigned to the metal service section of the Aluminum Co. of America in Rockdale, Tex. He previously served as a metallurgist for the company in the Davenport, Iowa, works.

A new firm, under the name of Nuclear Materials & Equipment Corp., has been formed at Apollo, Pa., with **Zalman M. Shapiro** as president, and **Frederick Forscher** and **Leonard Pepkowitz** as vice-presidents. The plant will manufacture fuel and control rod materials and associated material, recover fuel and control rod scrap for industry, and provide research and development services in chemistry and metallurgy for the atomic energy program. Dr. Shapiro and Dr. Forscher have both been associated with the atomic energy division of Westinghouse Electric Corp., Pittsburgh, while Dr. Pepkowitz was connected with General Electric's Knolls Atomic Power Laboratory in Schenectady, N.Y. Dr. Forscher is currently a member of the Committee on Literature classification.

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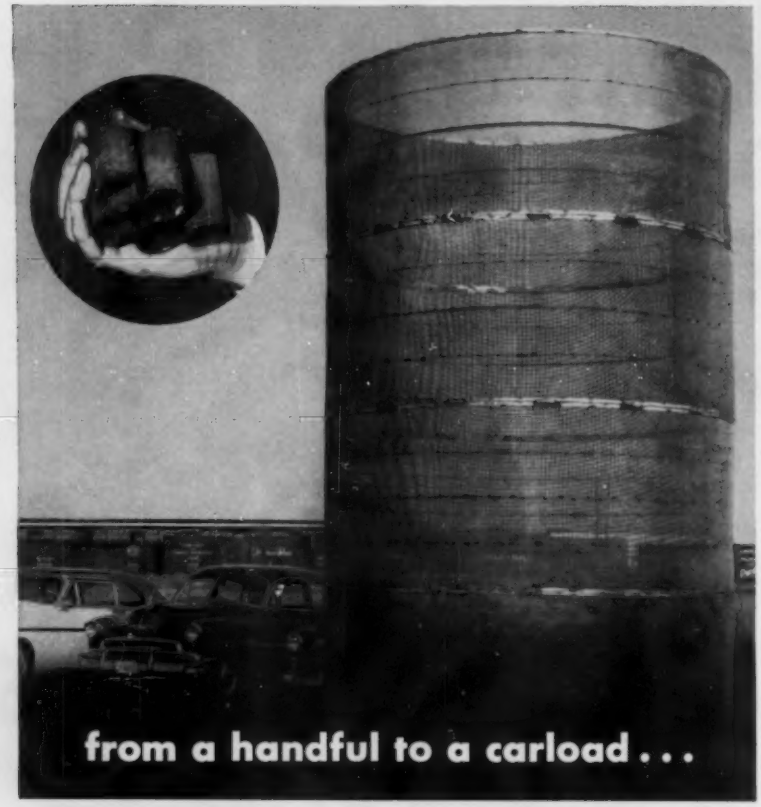

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Personals . . .

Richard E. Pawel is now serving as a first lieutenant in the U.S. Air Force at the Wright Air Development Center, Wright-Patterson Air Force Base, Dayton, Ohio, after having obtained his doctorate degree in metallurgy at the University of Tennessee.

James E. Hamer has taken a position in the new staff chemistry and metallurgy research center of Thompson Products, Inc., located in Euclid, Ohio. A 1956 graduate of the school of metallurgy of Carnegie Institute of Technology, he was formerly associated with a specialty steel producer in Pittsburgh as a stainless metallurgist.

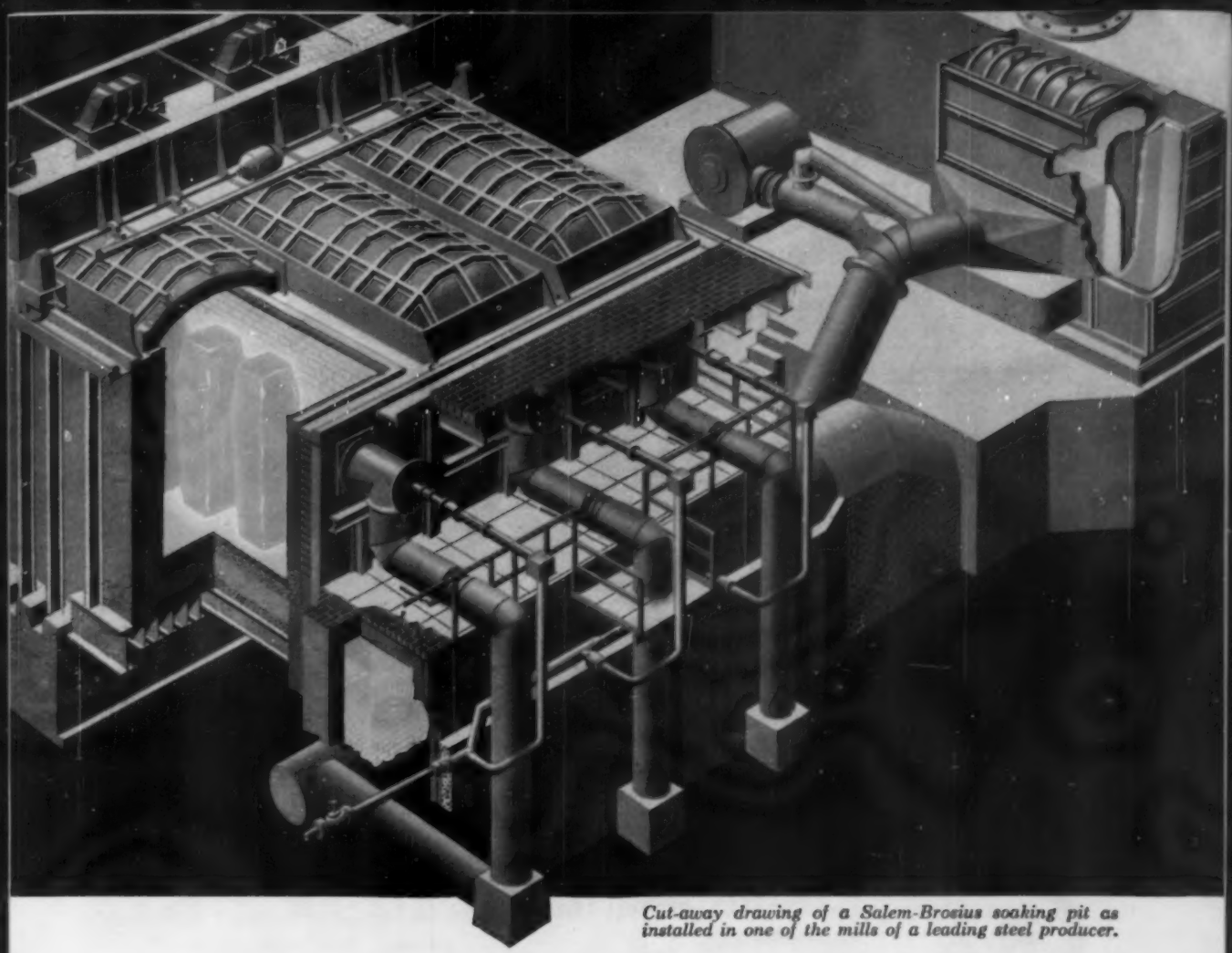
James W. Weber, after release from active duty as an officer with the Corps of Engineers in Germany, has accepted a position as engineer in the Hanford Laboratory Operation of the General Electric Co., Hanford Atomic Products Operation, Richland, Wash.

Benjamin C. Allen, who recently received his doctor of science degree in metallurgy from Massachusetts Institute of Technology, is now a research metallurgist in the light metals division of Battelle Memorial Institute, Columbus, Ohio.

Walter Showak received a doctor of philosophy degree in metallurgy from Pennsylvania State University in January and soon after became a research engineer on the scientific staff of the Ford Motor Co., Dearborn, Mich.

Robert J. Dybas, who entered the U.S. Army Ordnance Corps last fall, has graduated from the 9-0-2 Associated Ordnance Officer Basic Course and is at present renovation officer, 174th Ordnance Detachment, USAOrdSch, Aberdeen Proving Ground, Md. Lieut. Dybas was employed as a metallurgical engineer at the Aluminum Co. of America, New Kensington, Pa., before his entry into the armed service.

Richard A. Siergiej, a recent graduate of Lehigh University, now holds the position of metallurgist in the mechanical metallurgy and metallography section at the Knolls Atomic Power Laboratory of General Electric Co., Schenectady, N.Y.



Cut-away drawing of a Salem-Brosius soaking pit as installed in one of the mills of a leading steel producer.

Users are the best salesmen of Salem-Brosius soaking pits

"We have again specified Salem-Brosius soaking pits for our expansion program," reports an operating official of a major steel company using pits installed by several manufacturers. "The previous installation heated more steel ingots ready for rolling with less fuel consumption, less maintenance cost, and better temperature uniformity than any other type of pit in our plant."

Reports like this are typical, not only about soaking pits, but all other Salem-Brosius heating and heat-treating furnaces as well. Salem-Brosius engineers, both here and abroad, possess an enviable record for designing furnaces which produce maximum, high-quality output at minimum operating cost. If your expansion or modernization plans call for ingot soaking pits or any other heating or heat-treating furnaces, Salem-Brosius, Inc. would appreciate an inquiry.

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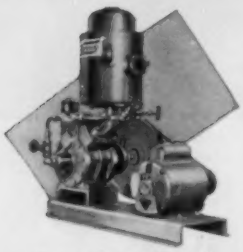

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Personals . . .

Andrew A. Kucher, director of Ford Motor Co.'s scientific laboratory, has been named director of the engineering staff. At present, he will have direct supervision of all activities of the central engineering staff and will exercise functional supervision of all other product engineering activities throughout Ford Motor Co. Mr. Kucher came to Ford in 1951 as director of the newly created scientific laboratory, and prior to that was affiliated with Bendix Aviation Corp.

The appointment of two district managers has been announced by the Electro Metallurgical Co., a division of Union Carbide and Carbon Corp., New York. The new Houston, Tex., district manager is **F. W. Hanson**, a sales and metallurgical service engineer with Electromet since 1939. **R. W. Wilson** has been named Chicago district manager. Coming to the company as a sales engineer in 1954, Mr. Wilson was previously employed by the Armour Research Foundation of Illinois Institute of Technology and the American Hoist & Derrick Co., St. Paul, Minn.

Robert C. Anderson, formerly chief metallurgist at W-K-M Co., Inc., Houston, Tex., a division of ACF Industries, is now a consulting metallurgical engineer in Houston.

James H. Johnston and **Edward R. Funk** recently organized the Vaculloy Corp. of Wooster, Ohio. The new firm is currently engaged in custom vacuum melting of titanium, steel and other alloys for research, laboratory and development purposes. Mr. Johnston is the corporation's president and chairman of the board, while Mr. Funk is vice-president and treasurer. In addition, Mr. Johnston is vice-president of Johnston and Funk Titanium Corp. and Johnston Stainless Welding Rods, Los Angeles; Mr. Funk serves as president of Johnston and Funk Titanium.

Vincent Brady has assumed new duties as superintendent of melting for the Pencoyd Steel & Forge Corp., Philadelphia. Prior to his new assignment, Mr. Brady was in charge of electric melting at Midvale Co., Philadelphia.

From left to right: Stanley Pyciak, Purchasing Agent; Richard Hammerstein, Park East Lansing Representative; J. H. McKlveen, Chief Metallurgist; William Pickell, Foreman Heat Treating Department.

"PARK'S NU-SAL and THERMO-QUENCH . . . give us excellent results . . . in austempering automatic transmission bands to exacting specifications."

J. H. McKlveen, Chief Metallurgist, Kelsey-Hayes Wheel Co., Jackson, Mich., says, "Our problem is one of supplying the heavy demands of the automobile industry for automatic transmission bands to their exacting specifications.

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"The reason we use Park Chemicals? Over a period of years, we've found Nu-Sal and Thermo-Quench meet our toughest requirements. When you are doing a high volume job, any stoppage is a major problem. Park chemicals have helped us reduce downtime—up production. And one other thing, you can't beat Park for service and delivery."

For complete data on Park Nu-Sal Neutral Salt write for technical bulletin H-2. For complete data on Park Thermo-Quench write for technical bulletin H-19. Park Chemical produces a complete line of heat treating and quenching materials and would be happy to help you work out a solution to your heat treating problems without obligation. Call or write today.

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PARK CHEMICAL COMPANY 8074 Military Ave. ● Detroit 4, Mich.

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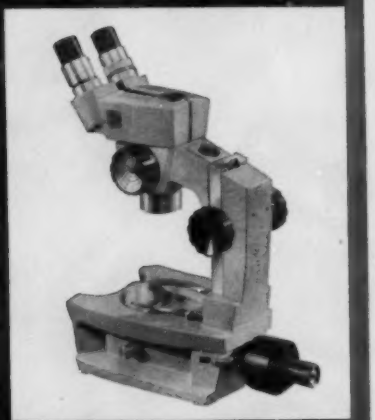

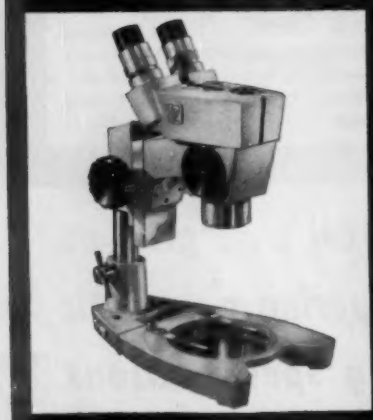

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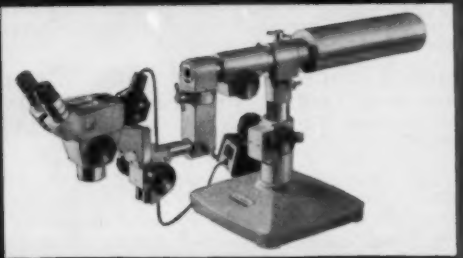

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Personals . . .

Walter J. Mollenauer and **William P. Youngquist** have been named assistant sales managers at Vulcan Crucible Steel Div. of H. K. Porter Co., Inc., Aliquippa, Pa. Formerly with Jessop Steel Co., Mr. Mollenauer joined the Vulcan Div. in 1956; Mr. Youngquist came to the company from U. S. Steel Corp. in the same year.

C. Douglas Yetman has accepted a position as sales engineer with the Magnethermic Corp., Youngstown, Ohio. Mr. Yetman was chief engineer with Heatronic Applications, Inc., before coming to Magnethermic.

Loren W. Smith, after 14 years as head of the metallurgy section of the materials department of Cornell Aeronautical Laboratory, Buffalo, N.Y., has joined the Symington-Gould Corp., Depew, N.Y. Mr. Smith will serve as assistant vice-president and director of metallurgical development of the company.

William C. Long is the manager of the new Detroit district sales office of the NRC Equipment Corp., a subsidiary of the National Research Corp., Newton Highlands, Mass. This office will serve all of Michigan as well as the Fort Wayne, Ind., and Toledo, Ohio, areas.

Aubrey Bukowski has become a member of the casting section of the metallurgy division of the Naval Research Laboratory, Washington, D.C. Since graduation from the University of Wisconsin in 1955, Mr. Bukowski has been with the Wehl Steel Co., Milwaukee, Wis.

Charles D. Coxe has assumed new responsibilities as manager of the metallurgical department of Handy & Harman, New York. His duties will include operation of the company's technical and assay laboratories, technical control in plants, and powdered metal products manufacturing. Mr. Coxe became associated with Handy & Harman in 1946 after ten years in research and development work with E. I. du Pont de Nemours & Co. and Remington Arms Co., and last held the post of assistant manager of the metallurgical department.

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Reactor-grade and hafnium-containing commercial-grade zirconium sponge will be produced in sufficient quantities to fill government and industry requirements. Leading metal converters and fabricators are now supplying zirconium mill and finished products.

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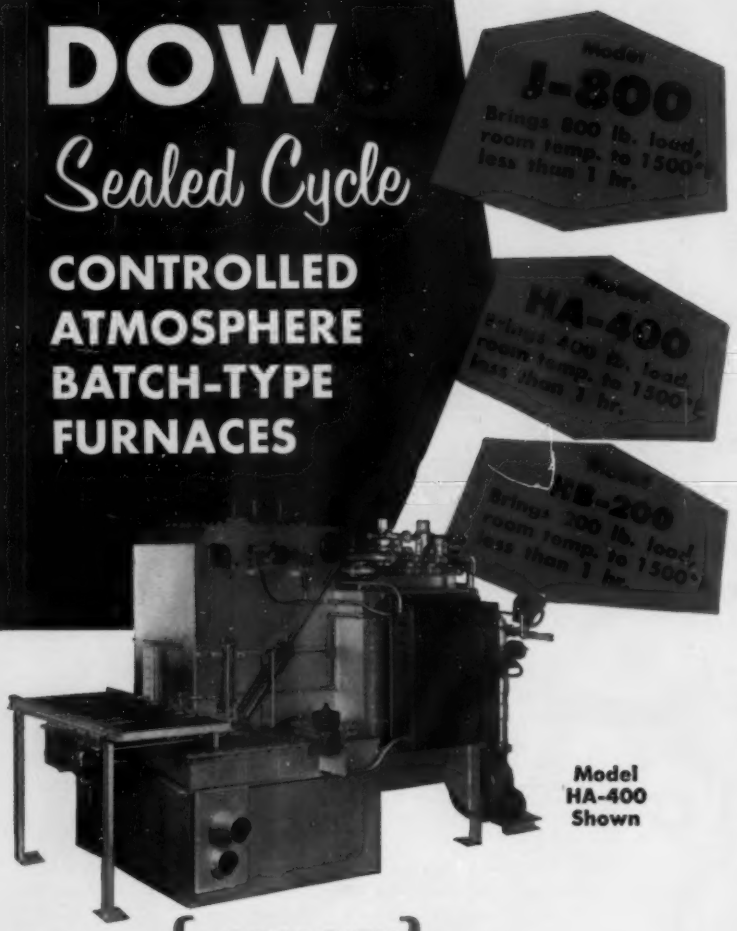
Model
A-800
Brings 800 lb. load, room temp. to 1500°F less than 1 hr.
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Brings 400 lb. load, room temp. to 1500°F less than 1 hr.
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Personals . . .

Harry D. Ambs, a recent recipient of a master's degree in metallurgical engineering from Rensselaer Polytechnic Institute, is now an associate metallurgist working on research and development projects in the sintered metals laboratory of the International Business Machines Corp., Endicott, N.Y.

Edward J. Ramaley, who was a senior tool engineer in the tool development group at North American Aviation, Inc., Columbus, Ohio, has moved to Denver, Colo., where he is now senior manufacturing engineer in the metallurgical group of the manufacturing research and development department of Martin-Denver. Mr. Ramaley was previously affiliated with Lockheed Aircraft, Burbank, Calif., and Battelle Memorial Institute, Columbus, Ohio.

David H. Wood, recently released from active duty with the Army, is now working as a metallurgical engineer at Battelle Memorial Institute, Columbus, Ohio.

Richard N. Wardell, formerly employed by the U. S. Naval Gun Factory, Washington, D.C., as a physical metallurgist, is now associated with the U. S. Patent Office as a patent examiner in the areas of general metallurgy, metal treating, metal founding and metallurgical apparatus.

Davis S. Fields, Jr., has received a doctor's degree from Massachusetts Institute of Technology and is now a research metallurgist at the Alcoa Research Laboratories, Aluminum Co. of America, New Kensington, Pa.

T. Howard Adair has been named manager of Atlas Titanium Ltd., Welland, Ont., a subsidiary of Atlas Steels Ltd. Mr. Adair joined the parent firm in 1934 as a metallurgical engineer, later became a member of the production metallurgical department, and since 1946 has served as chief plant metallurgist. In addition to these duties, he was appointed technical director of Atlas Titanium when the company was formed over a year ago, and served in this dual capacity until his latest appointment.

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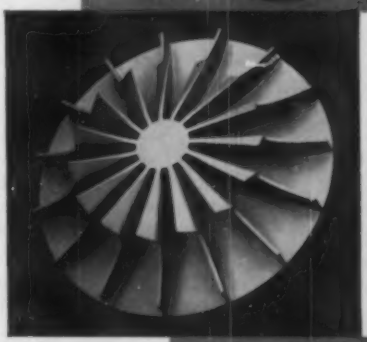

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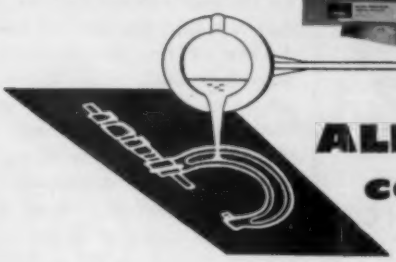

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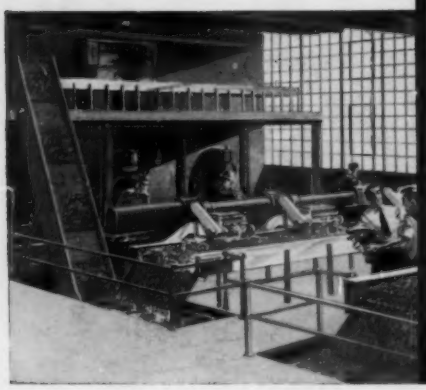

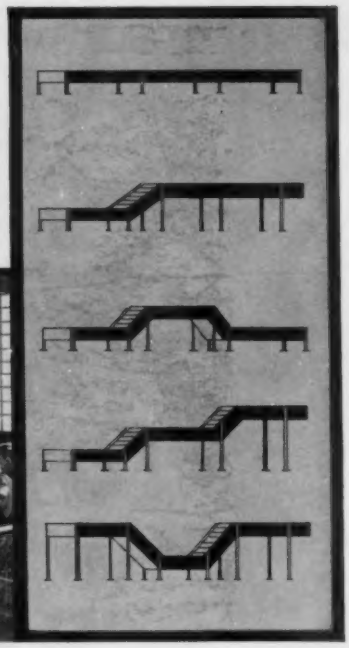

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Personals . . .

John B. West, district development engineer of the Atlanta district sales office of the Aluminum Co. of America, Pittsburgh, has been elected a director of the National Association of Corrosion Engineers. An employee of Alcoa since 1936, Mr. West was assistant chief engineer in the jobbing division before accepting his present position in 1945.

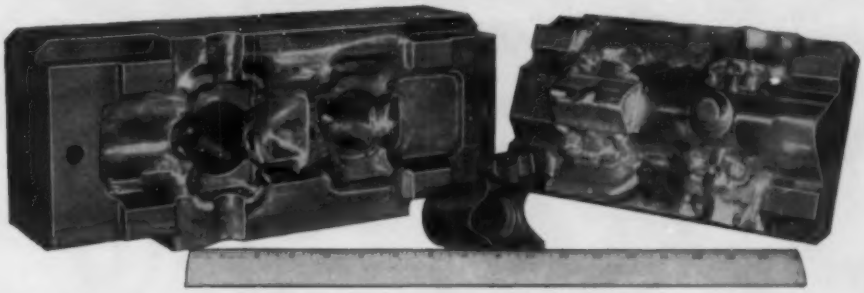
Harold B. Emerick, director of technical services for Jones & Laughlin Steel Corp., Pittsburgh, was elected national chairman of the Iron and Steel Div. of the American Institute of Mining, Metallurgical and Petroleum Engineers at the society's annual meeting in New Orleans in February. Mr. Emerick, who joined J & L in 1935 as a metallurgical inspector at the Aliquippa works, has served successively as assistant chief metallurgist, assistant to the vice-president of technology, and assistant director of technical services for the company.

H. H. Brandt has been added to the sales staff of Laclede-Christy Co., Div. of H. K. Porter Co., Inc., St. Louis. Previously employed by the National Carbon Co. and Bethlehem Steel Co., Mr. Brandt will serve as sales representative for the New York district.

Richard L. Reddy has joined the staff of the Metals Research Laboratories of the Electro Metallurgical Co., Niagara Falls, N.Y., a division of Union Carbide and Carbon Corp., as a research metallurgist. His previous technical experience includes four years as a research associate at Rensselaer Polytechnic Institute.

John F. Randall has been named director of the manufacturing engineering office of Ford Motor Co., Detroit. Affiliated with Ford for the past eleven years, Mr. Randall last held the post of assistant director of the manufacturing engineering office, and before that served as welding research supervisor for the engineering staff, supervisor of manufacturing engineering welding development and finally as assistant director of the staff office.

. . . and for forging dies and inserts, Latrobe's LPD is used for tough jobs!



Two station press insert manufactured and used by Ford Motor's Forging Plant in Canton, Ohio. It was made from Latrobe's LPD hot work die steel and is used to produce the Universal Flange Joint in the Drive Shaft Assembly of the 1957 Ford. The material being forged is SAE 1141 which is forged on a 2,000 ton forging press at a temperature of 2240° F.

The top and bottom inserts are heat treated to a hardness of Rockwell C 38-40. Average production for the top insert is approximately 16,000 pieces and for the bottom insert 8,000 pieces.

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Latrobe's LPD Hot Work Die Steel is a chromium-tungsten general purpose hot work steel possessing a fine balance of properties for high temperature work. It is an air hardening non-deformir.g steel with excellent machinability characteristics.

For your next hot work forging die or insert . . . use LPD. Call your Latrobe representative . . . a wide range of sizes are carried in warehouse stocks.

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you can get this brilliant finish directly on zinc die castings!

No electroplating--no mechanical finishing!

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NEW IRIDITE® (Cast-Zinc-Brite)

brightens zinc die castings by chemical polishing, protects against corrosion

NOW, FOR THE FIRST TIME you can get a brilliant, decorative finish directly on zinc die-cast parts . . . without mechanical finishing, without electroplating! The luster is provided by the *chemical polishing* action of new Iridite (Cast-Zinc-Brite) solution. Even surface blemishes, such as cold shuts, are brightened by this new process. No electrolysis. No special equipment. No specially trained personnel. Just a simple chemical dip for a few seconds and the job is done. And, this new Iridite has been *tested and proved* in production.

CORROSION RESISTANCE, TOO! New Iridite (Cast-Zinc-Brite) provides exceptional corrosion resistance for bright-type chromate finishes . . . also guards against blueing or darkening by eliminating zinc plate formerly required in bright chromate finishing of zinc die castings.

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LET US SHOW YOU what Iridite (Cast-Zinc-Brite) can do for you. Send us at least a half-dozen typical zinc die-cast parts for FREE PROCESSING for your own tests and evaluation. Or, for immediate information, call in your Iridite Field Engineer. He's listed under "Plating Supplies" in your classified 'phone book. *IMPORTANT: when you give us samples for test processing, please be sure to identify the alloy used.*

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Personals . . .

H. J. Siekmann is the newly appointed manager of an applied mechanics engineering group that has been formed at the General Electric Co.'s metallurgical products department, Detroit. The new specialized unit will be responsible for obtaining basic information on physical properties, machinability, and fundamental application requirements. It will also help to establish design and application criteria. Mr. Siekmann was in charge of the metallurgical products department's machinability laboratory for three years before his present assignment.

H. G. Johnstin has been chosen to manage the new metallurgical product development group of Vanadium-Alloys Steel Co., Latrobe, Pa. The new group will be in charge of the introduction and application of new toolsteel products to industry, and will institute in-plant test programs and tabulations, and evaluation results. Mr. Johnstin will be assisted by **Donald F. Griffin**, who recently joined Vanadium-Alloys after three years experience with the firm's Canadian subsidiary, Vanadium-Alloys Steel of Canada, Ltd., London, Ont.

Gordon H. Silver has resigned as staff consultant metallurgist for Titeflex, Inc., Springfield, Mass., to join the control engineering unit of Detroit Controls Corp., Norwood, Mass., as metallurgical engineering section head.

Stanley H. Peschel has been promoted from assistant roll designer to assistant superintendent of the 12 and 18-in. C Mills and 21 and 24-in. B Mills of Copperweld Steel Co., Warren, Ohio. Joining the company in 1940, Mr. Peschel left Copperweld in 1946 and spent four years with the Fenn Machine Tool Co., Cleveland, returning to Copperweld the latter part of 1950.

Orlando P. Metcalf, Jr., has left General Dry Batteries, Inc., in Lakewood, Ohio, to set up a consulting engineering service to industry on the mechanical and metallurgical problems in metals fabrication, with special emphasis on all phases of impact extrusion of both ferrous and nonferrous metals.

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If your product plans call for hollow cylindrical parts, give some thought to these facts. Manufacturers who had never seriously considered cast parts before are discovering important advantages in Sandusky centrifugal castings.

They're getting exceptional resistance to heat, corrosion, abrasion and stress, through the use of special alloys cast centrifugally . . . in diameters from 7" to 54", and lengths to 33 feet depending on diameter . . . and specially machined to specifications.

How can our versatile staff and facilities help you? Tell us your product requirements. Let us explore your ideas. Perhaps we can help solve your cylindrical problems through the vast foundry experience, metallurgical research and machining skills our 46 years offer.

Your request will bring more information promptly . . . or, if you prefer, a personal call by one of our engineers. Sandusky Foundry and Machine Company—Sandusky, Ohio.

Sandusky centrifugal castings offer you 4 important advantages:

1. ***SUPERIOR STRENGTH***—through non-directional mechanical properties
2. ***BETTER QUALITY***—machined castings are porosity-free
3. ***UNIFORM SOUNDNESS***—harmful inclusions are forced out by spinning motion
4. ***JOB-READY FINISHED CASTING***—reach you machined exactly to your specifications . . . eliminating extra costs from rejects, down-time, loss of production, etc.

Sandusky Centrifugal Castings

Stainless steels—plain carbon and low alloy steels—wide variety of copper base compositions

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Personals . . .

Harry P. Dobrow has joined Lockheed Aircraft Corp. as a production design specialist in their Burbank production engineering department to work on the F-104, Constellation series, electra turbo prop and Navy planes. Before coming to Lockheed, he was an advisory engineer on nuclear reactor components producibility with the atomic power division of Westinghouse Electric Corp., Pittsburgh, and prior to that was assistant to the vice-president of Alloy Engineering & Casting Co., Champaign, Ill.

George R. Kingsbury recently left the Clevite Corp., Cleveland, after 15 years as a metallurgist in various production, research and development operations, and has joined the technical operations staff at the Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N.Y.

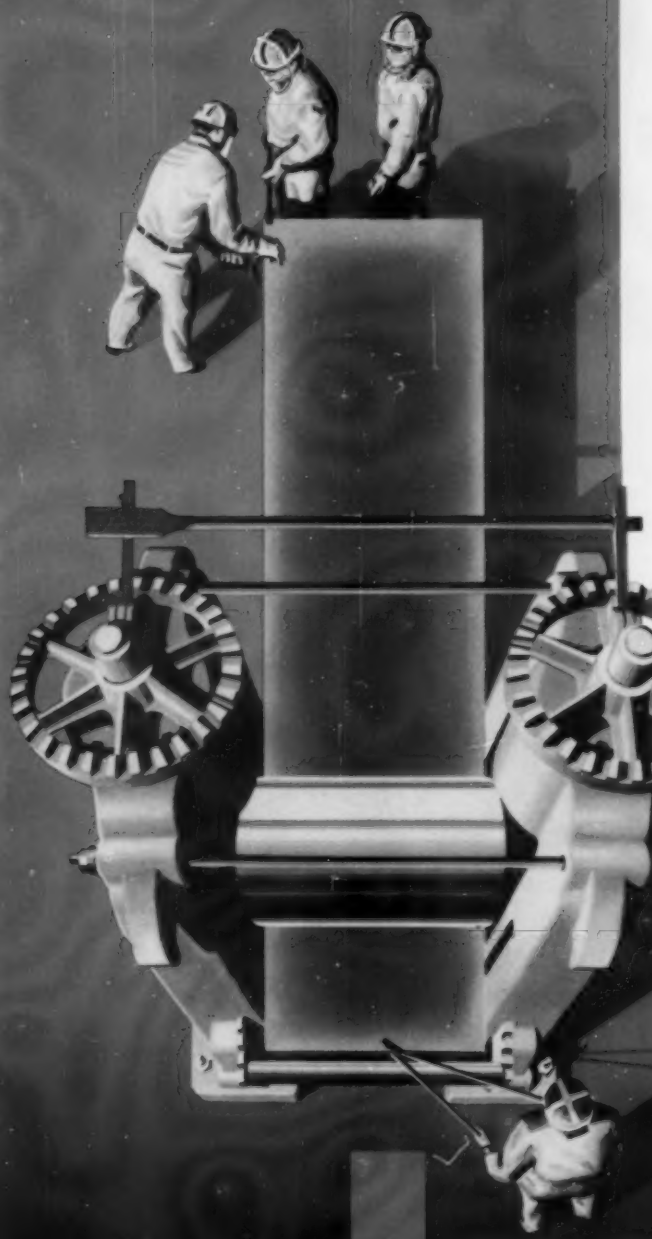
Burton C. Person, formerly associated with Esso Standard Oil Co., New York, has joined the John Wood Co., New York, as assistant to the chairman.

Rudolf H. Thielemann, chairman of Stanford Research Institute's metallurgy department, has been reappointed to two technical committees of the National Advisory Committee for Aeronautics. Mr. Thielemann continues as chairman of the Subcommittee on Power Plant Materials and also as a member of the Committee on Power Plants for Aircraft.

Samuel Storchheim has resigned his position as chief of nuclear manufacturing engineering and research with Glenn L. Martin Co., Baltimore, and is setting up an independent laboratory devoted to metallurgical research and development in Exeter, Pa., under the firm name of Metals Research and Development Corp. He will serve as president and technical director of the new organization.

Isaac Stewart, formerly chief engineer with the New York Testing Laboratories, Inc., New York, has announced the formation of a consulting engineering practice in the field of materials engineering and material failure evaluation.

How Jessop skill makes better saw steel



If you could peer down into the Jessop mill, chances are you'd see groups of men hand-rolling sheets of steel with a degree of skill and careful concentration that might seem excessive at first glance. *Yet it isn't.* These men are producing a very special steel—top quality high-speed sheet which is used in the making of hack-saw blades, woodworking tools, metal-slitting saws, general industrial knives, and the like. But *skillful finish rolling isn't all.* Jessop rigidly controls its melting formulas and pours small ingots specially designed for cross rolling. This insures a fine uniform grain structure so that the stock blanks well, forms well, swages well and has superior edge holding qualities. Remember, when you order your saw steel from Jessop, you are buying the finest that Jessop experience can offer. *And that's mighty fine steel.*

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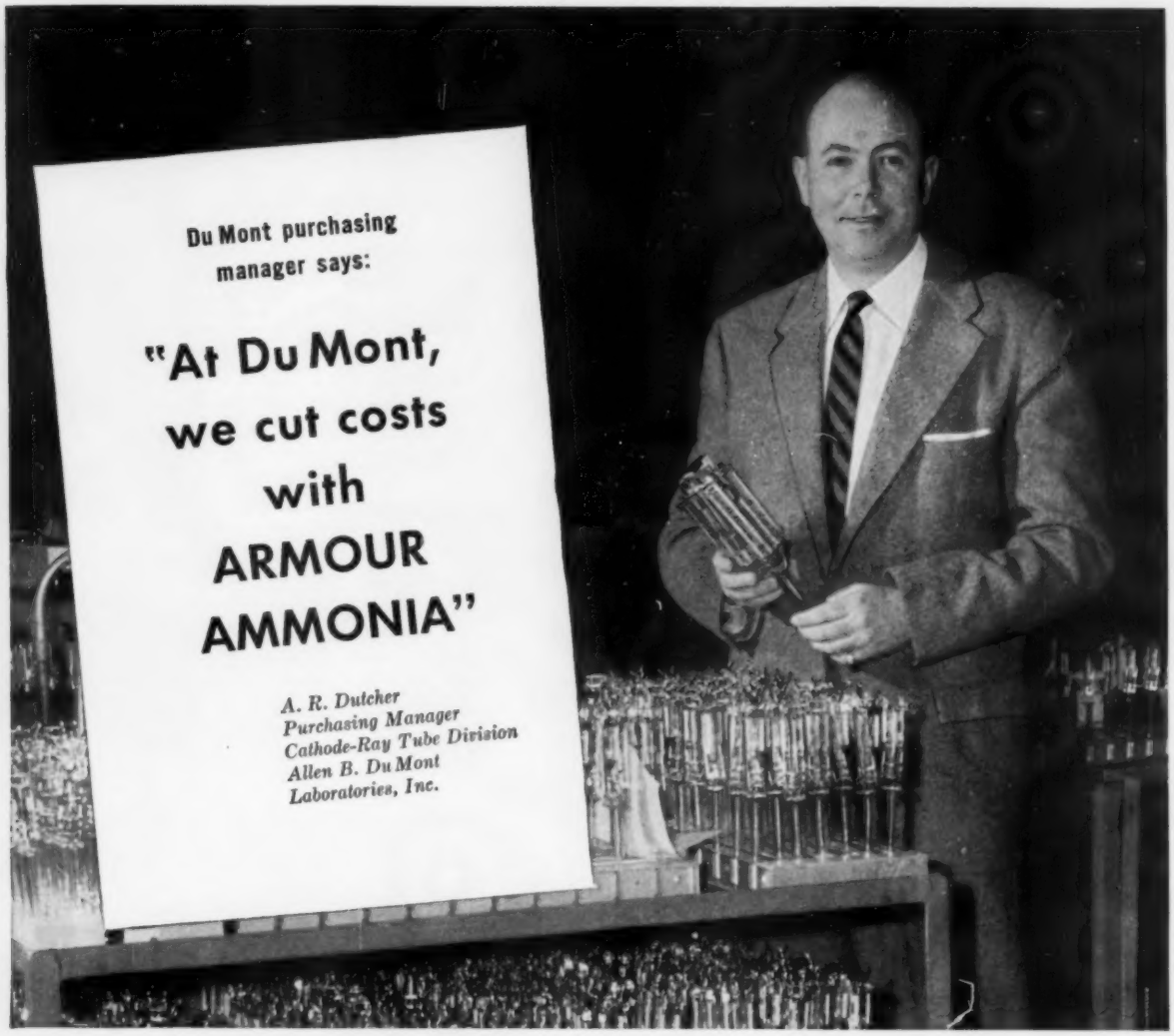
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New developments in the use of boron steels require the proper boron alloys in the steels' manufacture. Likewise, varying steel making techniques require different types of boron alloys. For each, there is a proper boron alloy, whether the objective is non-aging sheet steel or modifying rods for nuclear energy, for example. To meet competitive steel prices, manufacturers need to employ alloying elements judiciously.

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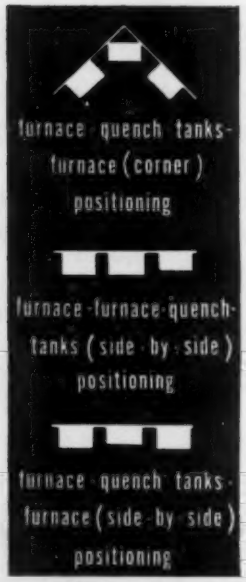

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Personals . . .

Walter E. Kingston will become executive vice-president of Sylvania-Corning Nuclear Corp., a company being formed as a jointly owned firm by Sylvania Electric Products, Inc., and Corning Glass Works. The proposed new company will take over the two parent organization's atomic energy activities. Mr. Kingston, who joined Sylvania in 1931, is now general manager of Sylvania's atomic energy division at Bayside, Long Island, N.Y., and will continue to have his offices there.

John M. Turbitt was recently promoted to district manager of the Metal Goods Corp. office and warehouse in Wichita, Kan. Prior to his promotion, he spent ten years as resident salesman in charge of Fort Worth, Tex., sales office. Mr. Turbitt also served as chairman of the North Texas Chapter for 1954-55.

Thomas D. Moore, after graduation from Purdue University in January, accepted a position with Armco Steel Co. He is working on special assignment to the assistant plant superintendent of melting and blast furnace operations at Middletown, Ohio.

Leo C. Powers, recently discharged from the U.S. Air Force Strategic Air Command, has returned to the Aluminum Co. of America's sales development division in Cleveland. While in the armed service, Mr. Powers was stationed at Fairchild Air Force Base, Spokane, Wash.

Milton P. Gussack has been chosen national sales manager of the General Bearing Co. and will supervise the firm's sales development in conjunction with recently increased production facilities. Mr. Gussack most recently was director of sales for Grant Pulley and Hardware Corp., Flushing, L.I., N.Y.

Robert E. Via has been discharged from the Army and is now a process engineer in the equipment and process engineering department of Grumman Aircraft Engineering Corp., Bethpage, L.I., N.Y. While in active service, Mr. Via was stationed at the Watervliet Arsenal, Watervliet, N.Y.

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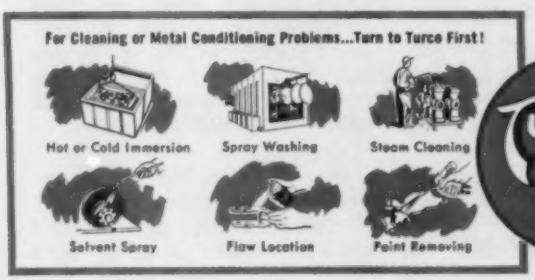

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Digests of Important Articles

Silvinite for Salt-Bath Hardening

Digest of "Properties of Sylvinite as a Medium for Heating Steel Parts for Hardening", by E. A. Smol'nikov, *Metallovedenie i Obrabotka Metallov*, No. 6, June 1955, p. 25-32.

SYLVINITE IS A LOW-COST native mineral that appeared to be promising for use in commercial salt-bath furnaces. Average composition of the samples used for commercial trials is as follows:

NaCl	69.98%
KCl	24.89
Insoluble residue	1.95
So_4	1.71
$MgCl_2$	0.55
Fe_2O_3	0.25
Moisture	0.28
$CaCl_2$	0.50

It can be seen that the ratio of NaCl to KCl is about 70:30, compared to 44:56 ratio of the eutectic mixture of these chlorides that is often used in commercial practice. In view of this difference, and also to obtain salts with lower melting temperatures, various mixtures were tested as well as the raw mineral. These mixtures, and their identifying letters, are shown in Table I. The last entry in the table is a salt mixture that is widely used in commercial practice and that was tested for comparison. The compositions E, K, and L were chosen after tests of the binary mixtures involved had shown that these were low-melting compositions.

Laboratory tests were first run to determine several important properties of the five salt compositions listed in Table I. The loss by volatilization was determined at 1560° F. by heating samples in a porcelain beaker and measuring the loss in weight for times up to 8 hr. The sylvinite sample behaved much like the commercial salt, S. There was an initial rapid loss of about 2.5% in the first hour, and then the rate of loss fell to a lower, linear rate such that after 8 hr. the total loss was about 8% for sylvinite and 7% for mixture S. The results for the other mixtures were about the same except for L, which had an 8-hr. loss of 15%.

Table I – Salt Mixtures Tested

SAMPLE	COMPOSITION	MELTING TEMPERATURE
No. 1	Sylvinite (Sample No. 1)	1360° F.
E	60% Sylvinite, 40% KCl	1200
K	66.7% Sylvinite, 33.3% $BaCl_2$	1260
L	50% Sylvinite, 50% Na_2CO_3	1150
S	78% $BaCl_2$, 22% NaCl	1180

Tests of corrosiveness of the bath toward steel were especially significant in view of the relatively high sulphate ion content of sylvinite sample No. 1.* These tests were made on steel 9 KhS which contains about 0.9% C, 1.4% Si and 1.1% Cr. Samples were heated in the various salt mixtures at 1470, 1560 and 1650° F. for times ranging from 5 to 180 min. For short times (up to about 15 min.) at the two lower temperatures the sylvinite caused about the same loss in weight as commercial salt S. This degree of corrosion was not visible to the eye. At the higher temperature or after 180 min. at 1560° F. the sylvinite was more than three times as corrosive as salt S. The other salt mixtures behaved similarly to sylvinite. The decarburizing effect of sylvinite was nearly the same as that of S, although the other mixtures tended to decarburize more seriously.

Sylvinite of analysis used for commercial trials is generally superior to No. 1, which was used for the laboratory tests. Also, in view of the laboratory results, the mineral was used directly, without mixing with other salts, although the molten bath was deoxidized with 1% borax initially and after each 8 hr. of operation. Heat treatments were carried out on various kinds of tools made of carbon steels, 1% Cr steel and steel 9 KhS. The hardened tools were satisfactory, and the bath behaved like the usual commercial baths as far as factors such as carry-out loss and ease of cleaning the quenched tools were concerned. Sylvinite is now being used in normal commercial practice in Russia.

A. G. GUY

*TRANSLATOR'S NOTE: A reference given in this connection is to "Som Taur, Transactions A.S.S.T., No. 5, 1924". We hope Sam Tour is recognized behind this disguise.

Measuring Arc Welding Costs

Digest of "Arc Welding Costs: an Example of Total Production Analysis", by A. G. Thompson, *British Welding Journal*, Vol. 3, September 1956, p. 403-414.

THIS IS a report on an investigation by the British Welding Research Association of a method of measuring welding output. Its purpose was to develop a means of comparing the efficiency of output in different shops. It was decided to obtain actual data on relevant man-hours over a range of welding applications and relate this information mathematically or graphically to known satisfactory measures of output by total production analysis.

Data obtained from actual arc welding operations for a wide variety of fabrications covered a range of tank-like products varying in weight

VICTOR TORCH with cutting tip of Anaconda Tellurium Copper, which has the resistance to heat and wear required to maintain uniform flame characteristics through a long life of service.

Tellurium Copper makes better cutting and welding tips

Two typical Victor torch tips of Anaconda Tellurium Copper-127 shown full size.

THE PROBLEM: Victor Equipment Company of San Francisco first used regular leaded copper rod in making tips for its line of cutting and welding torches. In some applications, however, the leaded copper did not stand up under high heat conditions.

THE SOLUTION: Victor tried Anaconda Tellurium Copper-127 Rod and found the answer. The Tellurium Copper had a much higher heat resistance. This meant long, trouble-free service for its precision-made cutting and welding torches in all types of applications. At the same time, the Tellurium Copper provided uniform machinability, especially important in drilling the deep holes prior to completion by swaging on mandrels.

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It is the function of the Technical Department of The American Brass Company to assist metal users in the selection of Anaconda Rod. This service is at your disposal without charge or obligation. Comprehensive data on composition and machinability of standard Anaconda Rod Alloys, together with specification references, weights and dimensions, are available in Publication B-3. For this booklet – or technical assistance – write: The American Brass Company, Waterbury 20, Conn. 5765

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Welding Costs . . .

from 0.2 to 35 tons. These data included man-hours preparation, man-hours welding, product size, product weight, plate thickness, and length of joint. From these, the author proceeded to device relationships between weldors man-hours and the variables of fabrication weight, joint length, and average thickness, using an equation of the form:

$$H_w / J = a + bt$$

where H_w represents weldors man-hours, t is average thickness, J is joint length, and a, b, and c are constants.

Such a step-by-step analysis is admitted to be different from the usual approach where the method of multiple correlation is used, giving an equation of the form

$$H_w = a + bt + cJ$$

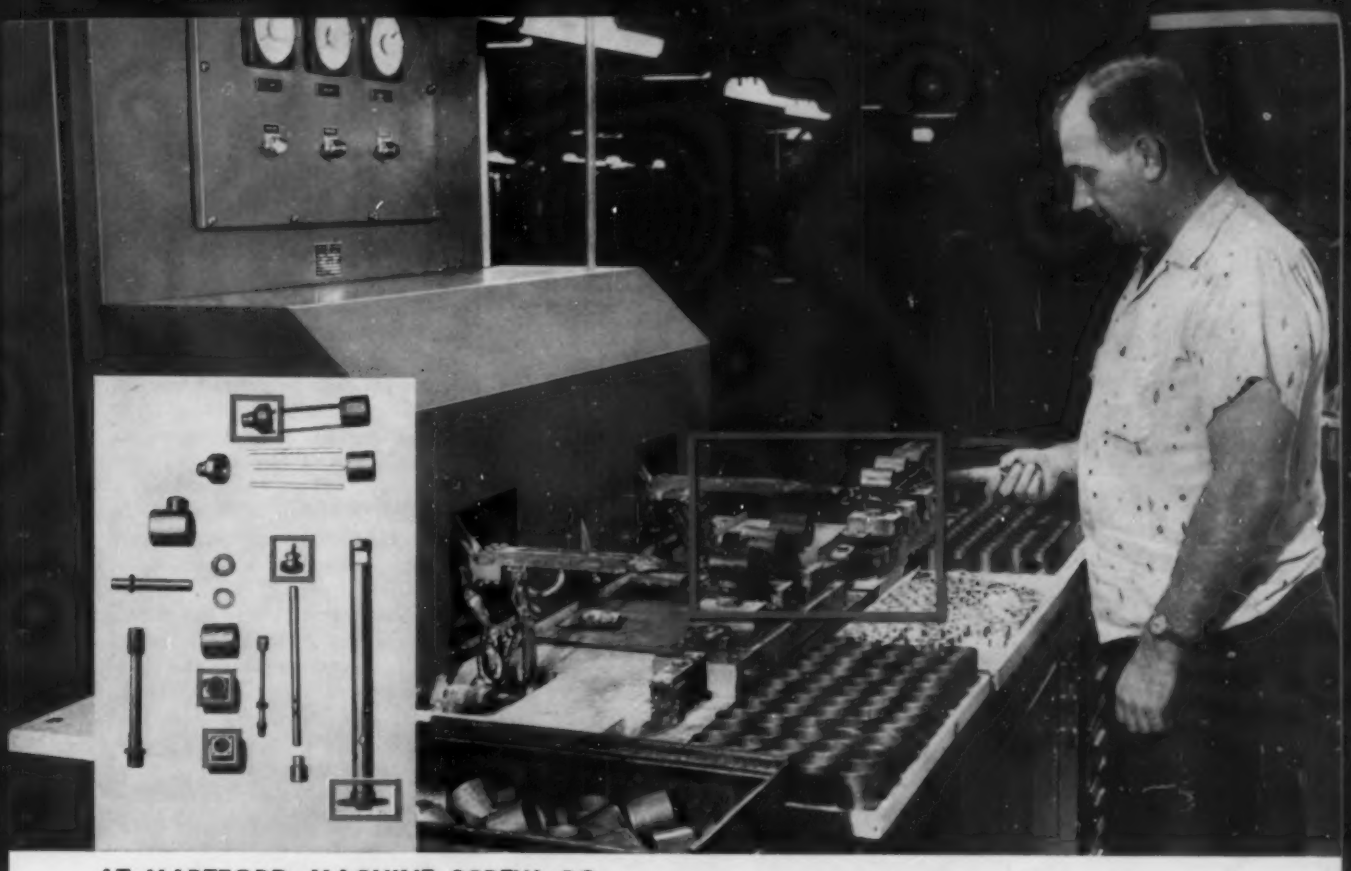
However, several advantages are claimed for the first relationship: The computational work is often less, two-dimensional graphs each showing an effect of an important factor can be used, and the progressive analysis can be stopped at any point where sufficient information is at hand to make the decision required.

In the actual use of the step-by-step technique, a coefficient is used to determine how well two quantities are related. The closer this coefficient is to 1, the better the correlation.

The first stage of the study correlated weldors man-hours with weight of product. It gave a coefficient of 0.996 (showing that a strong interrelation exists between these factors).

The second stage relating weldors man-hours to weight of product and average plate thickness failed to give a useful correlation. In the discussion, the author develops the point that for the data used, man-hours per ton is independent of plate thickness. It is pointed out that this is a coincidence and it should not be assumed that such a relation will not provide useful information for other types of products.

In the third stage where weldors man-hours were related to weight of product in tons, average plate thickness, and length of joint, a correlation coefficient of 0.992 was obtained. *(Continued on p. 136)*



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General Electric induction heaters braze 20 different parts, help cut rejects 91%

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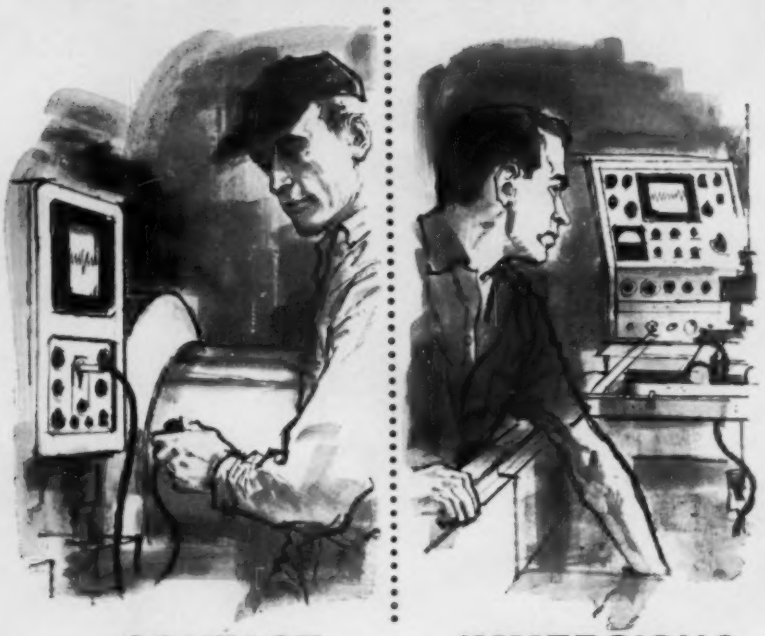

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Welding Costs . . .

Numerous other analyses of the same arc welding production data were made and are discussed. They point out the need for knowing all the details of production before an analysis of the measures of output can be made. In each case involving a job done under extenuating circumstances, the job data were eliminated from the calculations, resulting in improved relations.

From the above relationships, a table of accuracy of forecasts is presented which permits an estimate of error of forecast for new work.

For management, relatively simple relationships can be established for estimating, planning, and setting up of production targets by the "total production analysis" method. These same relationships can be used to make comparisons between different shapes or different times in the same shop if they are made on like production. The techniques outlined may also be used for cost control.

The work outlined in the paper is applicable to the determination of production indices. An index such as man-hours per foot of joint reduced to a standard thickness is suggested. Methods of getting a factor for reducing a standard thickness are discussed. R. EVANS

Effect of Impurities on Properties of Pure Iron

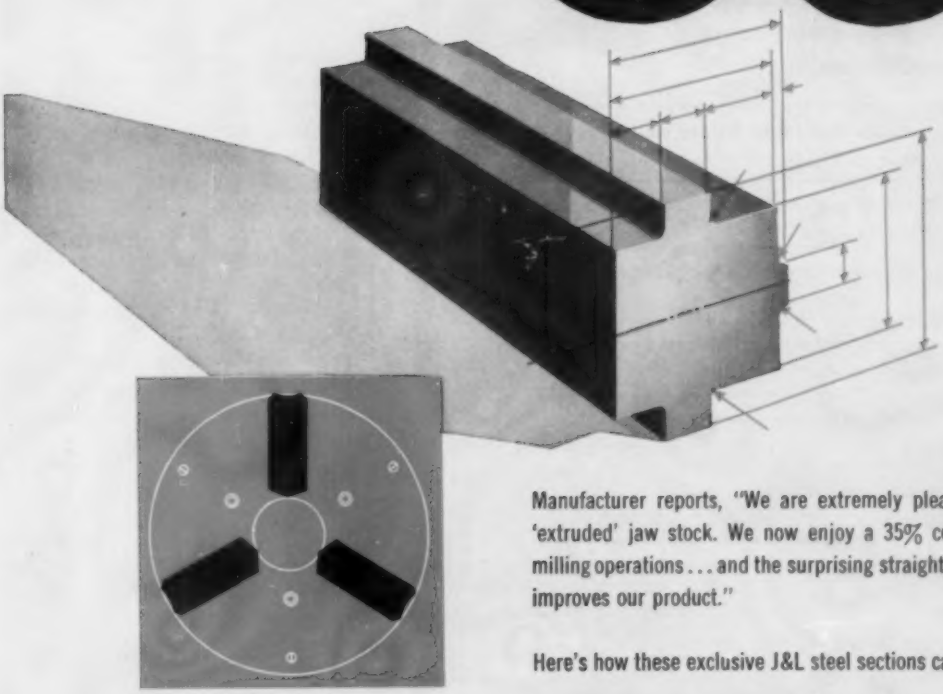
Digest of "The Effect of Impurities on the Properties of Pure Iron," by J. D. Fast, *Stahl und Eisen*, Vol. 73, p. 1484-1496; translated and condensed in *Metallurgia*, Vol. 54, September 1956, p. 123-127.

EVEN IN unalloyed steels small amounts of impurities such as manganese, carbon, sulphur, phosphorus, oxygen, nitrogen and hydrogen are present. Undesirable phenomena such as aging are attributed to these various impurities. However, in order to study the aging process thoroughly a comparison of absolutely pure iron with impure iron containing known amounts of impurities is necessary.

Pure iron is made by melting 2 kg. of carbonyl iron in a high-frequency induction furnace under a vacuum of 10^{-5} mm. When molten, oxygen-

J&L hot extruded, cold drawn chuck jaw section reduced milling cost

35%



Manufacturer reports, "We are extremely pleased with this purchased 'extruded' jaw stock. We now enjoy a 35% cost reduction on our jaw milling operations . . . and the surprising straightness of the extruded bars improves our product."

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5	**How to strip paint from aluminum.** See pages 22 to 26.
6	**How to clean magnesium.** See pages 27 to 29.
7	**How to install cleaning tanks and spray-washing machines.** See pages 31 to 35.
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9	**How to clean engine test cells.** See page 40.

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free hydrogen is passed over the metal for several hours. When the oxygen ceases to evolve (as indicated by the appearance of an 18-8 stainless steel strip in the gas stream) the total content of carbon, oxygen and nitrogen is considered to be below 0.001%. The hydrogen still in solution is removed by evacuating to 10^{-3} mm. of Hg.

Nonvolatile alloying elements such as nickel or molybdenum can be added to the original melt. Elements of high oxygen affinity are added via a tube sealed into the side of the vacuum chamber, the internal exit of which is directly above the surface of the melt.

The quench aging behavior of pure iron prepared in the above manner is compared with irons containing 0.03% oxygen, 0.02% nitrogen and 0.04% carbon, respectively. Additions of 0.5% manganese are made to some of the iron samples containing nitrogen and carbon. Pure iron shows no quench aging effects due to carbon and nitrogen. The slight effect of oxygen suggests that it is less soluble in alpha iron or that, unlike carbon and nitrogen, it enters into substitutional solid solution with alpha iron. The presence of 0.5% manganese practically inhibits precipitation in iron containing nitrogen but has no effect on carbon in iron.

It appears that nitrogen is more important than carbon in producing strain age hardening. Oxygen is found to have no effect on the aging properties.

A comparison of the tensile strengths and ductilities of samples containing 0.02% nitrogen or 0.04% carbon with those of pure iron shows that blue brittleness is dependent on the nitrogen content of the steel.

Impact tests show that the presence of more than 0.01% oxygen in iron is sufficent to cause brittleness. Failure at low temperature in irons containing oxygen takes place at the grain boundaries. Traces of carbon (0.002%), however, counteract the undesirable effect of 0.01 to 0.1% oxygen.

The strain aging effect may be attributed to the combined influence of dislocations and dissolved carbon or nitrogen atoms. Dissolved atoms generally diffuse into regions of

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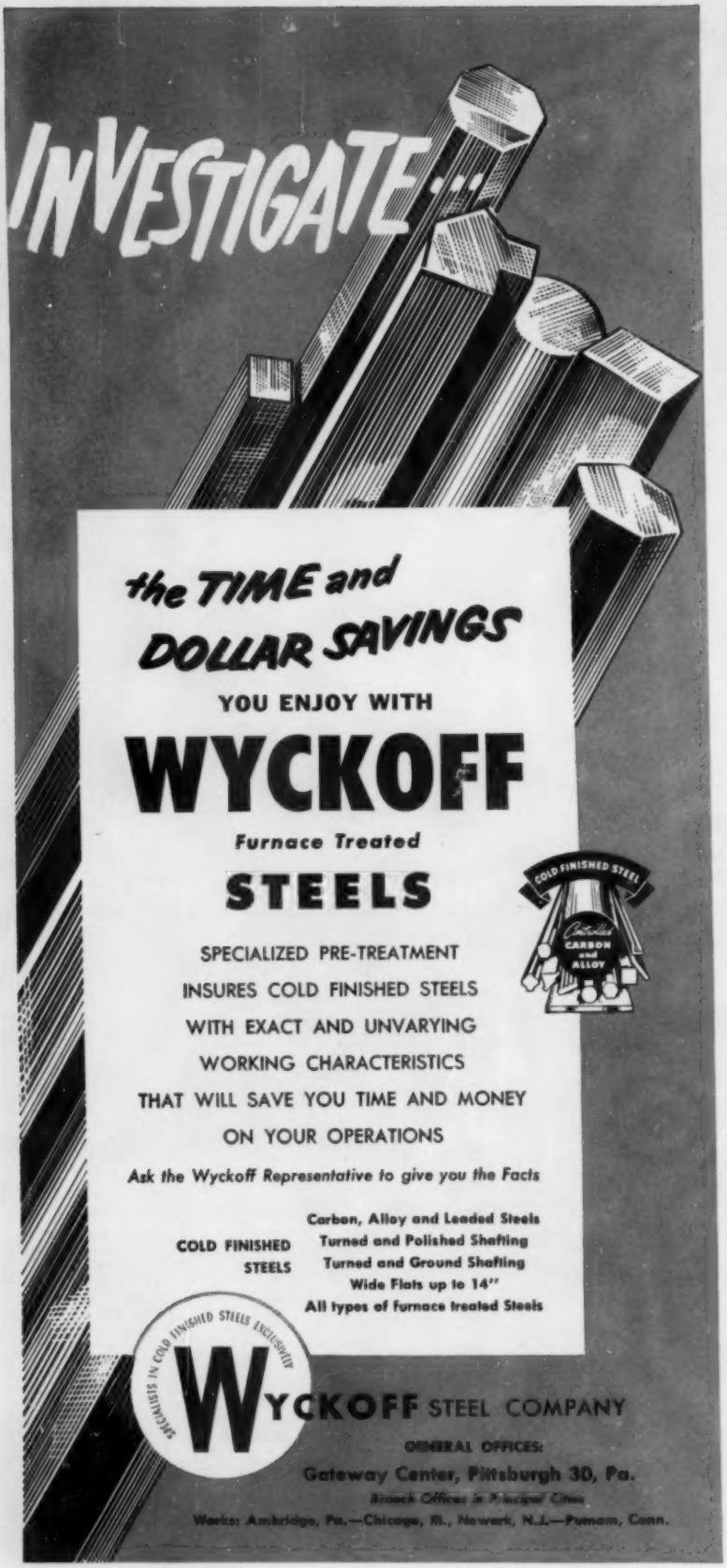

Pure Iron . . .

highest stress when they occupy positions of lower free energy. A "precipitate" of foreign atoms is, therefore, formed at temperatures below 400° C. (750° F.) consisting of one carbon or nitrogen atom per layer of iron atoms. When a dislocation separates from such a one-dimensional precipitate of foreign atoms, the metal is placed in a state of higher energy. When the metal is deformed the dislocations are free and strain aging occurs by the diffusion of carbon or nitrogen atoms toward these dislocations where they are fixed, with a consequent increase in hardness.

W. A. MORGAN

Honeycomb Core Materials

Digest of "Honeycomb Core Materials", by A. J. Carah, *Ordnance*, Vol. 41, January-February 1957, p. 727-729.

PANEL MATERIALS of "sandwiched" construction date back to the introduction of the corrugated paper carton in 1875. However, extensive structural use of the concept did not appear until the development of synthetic resin adhesives capable of bonding the core materials to metal, and metal to itself.

A recent promising development is stainless steel honeycomb for high-temperature high-strength installations. Cells are hexagonal or square, of stainless steel foil spot welded or brazed together. Assembly into panels is by dry hydrogen brazing.

Honeycomb core material, bonded into panels, is capable of working the face materials up to their yield strength. The core thus carries shear, tension or compression components normal to the skin, and stabilizes the faces to prevent buckling.

Where rigidity and light weight must be combined, honeycomb panels are ideal materials, making them particularly useful for airborne applications or where parts must be handled with minimum manual effort as, for example, scaffolding or tooling platforms.

"Sandwiches" with honeycomb core provide exceptionally smooth, wrinkle-free surfaces at all loads up

AGF HEAT TREATING PRODUCTION LINE AT HOLO-KROME INSURES UNIFORM TENSILE STRENGTH

HOLO-KROME features socket screw products having toughness as well as uniformity of hardness and strength. AGF Furnace equipment contributes to this high standard.

POSITIVE ASSURANCE that every Holo-Krome socket screw will have correct tensile strength and a uniform distinguishing color, characteristic of quality heat treating, is embodied in the above AGF installation.

This AUTOMATIC production line consists of:

(1) An AGF No. 240 Heating Machine which hardens the screws in a controlled atmosphere at the rate of 400 to 500 pounds per hour.

(2) An AGF Conveyorized Quenching Tank.

(3) An AGF No. 242 Heating Machine which tempers the work utilizing residual quenching oil remaining on the work pieces to produce an attractive black finish, which then discharges into

(4) an AGF Conveyorized Quench Tank equipped with a vibrator discharge chute for removing the oil and carrying the work to the packaging operation.

Your heat treating of fasteners or other small parts like stampings, screw machine products and precision castings can be accomplished with greater uniformity and quality control and at lower cost in AGF equipment.

PIONEER Furnace Engineers and experienced metallurgists at AGF will weigh your needs and make a proper recommendation without obligation.

Write today for the name of nearest AGF factory trained representative located in major industrial areas.

AMERICAN GAS FURNACE CO.

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HEAT TREATING TECHNIQUES IMPROVED AT RIVERSIDE FOUNDRY

Illustrated above is the Hevi Duty Furnace used to determine heat treating procedure and the metallurgical characteristics of new alloys or special steels, at Riverside Foundry in Bettendorf, Iowa. The establishment of the proper time and temperature cycles for the treating of various castings has increased production while reducing rejects.

Engineered features that produce the heat treating results you want

Only Hevi Duty Furnaces assure uniform temperature with the long life "Return Bend" heating elements that radiate the heat from the six sides of the work chamber. Ceramic refractories rigidly support the round rod elements which have proven durable under the most severe operating conditions. Because the Return Bend Elements have less surface area per cross-section to oxidize or deteriorate, element life is greatly increased.

There is a Hevi Duty Furnace in the size, type, and temperature range to handle your most critical type of heat treating. Tell us about your requirements.

Write for Bulletin 441.

HEVI DUTY ELECTRIC COMPANY

MILWAUKEE 1, WISCONSIN

Heat Treating Furnaces... Electric Exclusively

Dry Type Transformers *Constant Current Regulators*

Honeycomb Cores . . .

to the yield strength of the face material and their cost per square foot is low in comparison with panels of equal rigidity in other types of construction. Extremely thin facing may be used, core materials are inexpensive and tooling cost for flat panels is negligible.

Certain disadvantages must be recognized, some inherent in the material, some because the state of the art is young. Inspection methods for determining the quality of the adhesive bond of the core to face panels and of edge members to core and faces are not yet developed to the point where complete confidence is assured.

One recent and reliable inspection method makes use of an ultrasonic bond meter, developed by the Stanford Research Institute. It indicates a change in the damping of an ultrasonic beam, caused by an unbonded area (or flaw) in a panel, on a cathode ray tube.

A serious problem is moisture absorption in the paper or fabric honeycomb cores. This leads to corrosion of the faces and other structural members in contact with the wet core. The result may be appreciable lowering of panel strength and also weakening of the bond between core materials and faces as a result of interaction of corrosion products with certain types of adhesives. Static tests of missile fins returned from service have shown a reduction in strength of up to 50% due to corrosion of magnesium structural members in combination with epoxy adhesives. Aluminum alloys are subject to the same deterioration but to a lesser degree.

Impact strength of a honeycomb panel is a somewhat different concept than in respect to solid metals. For the latter, it is a measure of the resistance to failure in bending across a notch when the specimen is subjected to a blow. For honeycomb, it is the resistance to local crushing of the core under a blow upon one of the faces. The resistance of honeycomb cores to blows of this sort is low, but the over-all effect of such a crushed and weakened area in a typical sandwich structure is negligible unless large areas have been crushed.

ARTHUR H. ALLEN

• Sharon has been a prime supplier of quality steels to the Garden Tool Industry for more than half a century. Our metallurgists and engineers have played important roles in the development of the special stainless steels, spring steels, cutting edge steels, forging steels and other quality specialty steels that have enabled the industry to constantly improve product quality.

SHARONSTEEL

For 56 Years a Quality Name in Steel

245

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How to get the longest tube life per dollar! *Ask the experts!*

THE Timken Company offers 22 different high-temperature tube steels to solve your problems of heat, pressure, corrosion and oxidation. *One* of these tube steels has the analysis most suited to your needs, gives you maximum tube life per dollar of cost.

To find this analysis, *ask the experts!*—the metallurgists of The Timken Roller Bearing Company.

More than 20 years of experience has made Timken Company metallurgists recognized authorities on high-temperature steels. You put this backlog of experience to work for you when you consult these experts. They'll study your specific requirements, then recommend the one tube steel that fits them—most economically.

And you can be sure of uniform high quality in the Timken steel you get. One reason: we make our own fine alloy steels in electric furnaces. This enables us to maintain rigid quality control from melt shop through final inspection.

Timken Company metallurgists will be glad to help you solve your tube steel problems. When you *ask the experts,* you get longest tube life for your dollar. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO".

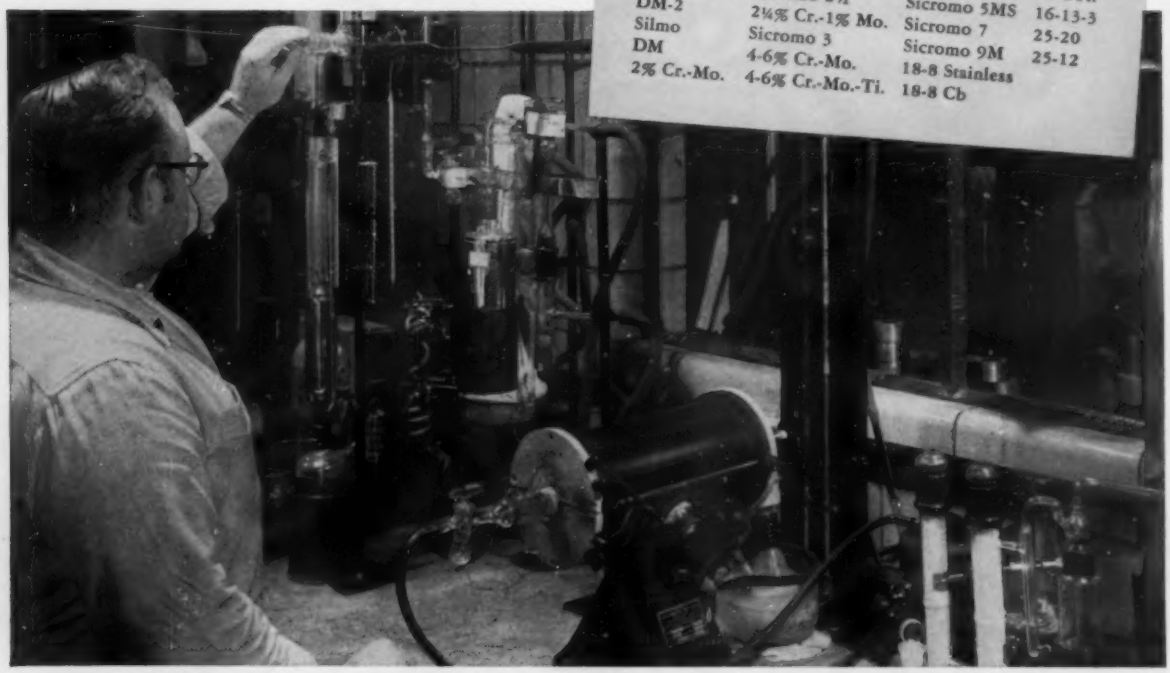
This month's report is on:

DM-2 STEEL

Suggested as a substitute for 0.50% Mo. steel. Has greater creep strength and somewhat better corrosion and oxidation resistance than 0.50% Mo. steel. For use in cracking furnace tubes, high pressure boiler tubing, superheater tubing and high temperature steam piping.

22 TIMKEN® STEELS FOR HIGH TEMPERATURE SERVICE

Carbon	Sicromo 2	Sicromo 5S	18-8Ti.
Carbon-Mo.	Sicromo 2½	Sicromo 5MS	16-13-3
DM-2	2¼% Cr.-1% Mo.	Sicromo 7	25-20
Silmo	Sicromo 3	Sicromo 9M	25-12
DM	4-6% Cr.-Mo.	18-8 Stainless	
2% Cr.-Mo.	4-6% Cr.-Mo.-Ti.	18-8 Cb	



This chlorination equipment helps us determine cleanliness of our steel by purifying extracted non-metallic residues. It's one of many ways we make sure you get steel of uniform high quality.

TIMKEN *Fine Alloy* STEEL

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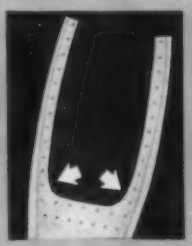
DoALL Demon Saw Band makes world's fastest machining method . . . even faster

Slice through toughest steel 6 times faster!

Jobs formerly done on mills, planers, shapers, lathes now done faster and for less with DoALL . . .

SLOTTING job took 325 minutes on a milling machine . . . 72 minutes on DoALL.

SPLITTING. Cutting time reduced from 10.8 to 3.6 minutes on a DoALL.



CONTOUR steel forging. No machine but a band machine could do it. Time: 7.8 minutes.

CUTTING FROM SOLID. DoALL saved 19% in time.

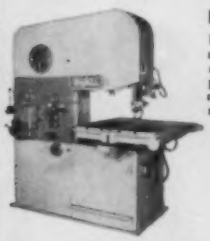
CUT GRINDING RELIEF. 78% time savings. One man in one hour does former 4 hour job.

CUT-OFF TITANIUM. 6½" dia. x .030 thin wafer cut at 1.2 in. per min.

DoALL Demon high speed steel saw bands slice through the toughest steels up to 6 times faster—last up to 10 times longer than any saw band ever produced. They will machine up to 10,000 square inches of mild steel at 10 square inches per minute and withstand temperatures up to 1100° without losing tooth hardness. They work fast at frictional heats that would burn up ordinary blades.

The continuous cutting Demon blade will deliver cuts never before possible. But what's more . . . with *the combination of DoALL Demon blade and DoALL Contour-matic,* jobs formerly done on expensive milling machines, shapers, planers and even lathes are now being done faster and at far less cost. That's because the band machine requires little fixturing, cuts faster, right to the layout line, rather than reducing expensive materials to a pile of worthless chips—and the DoALL machine *costs only* ⅕ *to* ½ *as much as other machine tools.*

Shown at left are just a few examples of the production notching, slitting, cut-off, slotting, 3-dimensional, contour and compound angle cuts possible on the DoALL—The world's newest, fastest and most economical machining method.



New DoALL Contour-matic

Hydraulic feed table, integral coolant system, tilting table, infinitely variable speed and feed, high horsepower, greater rigidity . . . has more, does more than any other band machine made.

C58 Automatic Cut-off

Automatic indexing, variable speed for sustained high production cut-off work. Any type or stock thickness.

SB-57R

Ready, Set, GROW... with

REVERE ALUMIN SHEET

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New Revere Aluminum Sheet Mill
Chicago, Ill.

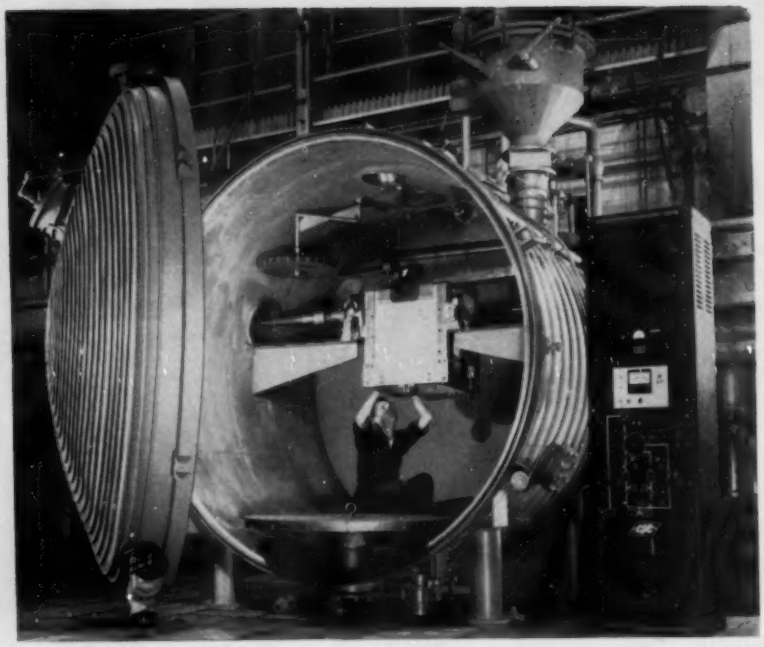
You will find that Revere Aluminum Sheet passes smoothly and economically through your processes, that it brings to your products all the advantages you expect from fine aluminum.

Three Revere plants, located in the East, the Mid-West and on the Pacific Coast, can bring mill service and technical consultation close to your own doorstep. These plants will have the backing of Revere's primary aluminum operation, scheduled to begin production in 1958.

It will pay you to tie the growth of your business to the most dependable sources of supply—such as Revere, which is in aluminum in a BIG WAY. Revere Copper and Brass Incorporated. Founded by Paul Revere in 1801. Executive Offices: 230 Park Avenue, New York 17, N. Y.

Revere Aluminum Mill Products include coiled and flat sheet, both plain and embossed, circles, blanks, Tube-In-Strip, extruded products, seamless drawn tube, welded tube, rolled shapes, electrical conductors, forgings, foil and frozen food containers.

← Projected for 1957: New Revere Aluminum Sheet Mill Santa Ana, Calif.



CEC's new 300 to 1000 pound vacuum induction melting furnace.

Get a vacuum furnace that *grows* with your needs

Save costly alterations, or the purchase of another furnace, when your requirements change. Make sure you get these features:

Flexible capacity. Expand the furnace's basic 300-pound capacity to as much as 1000 pounds simply by changing the crucible-coil.

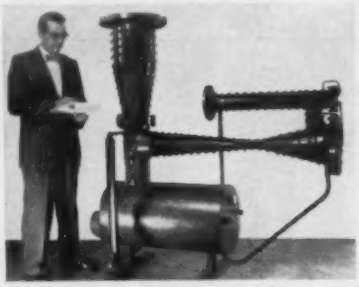
Add an interlock valve to the charging assembly and process as much as 3000 pounds of metal without breaking vacuum.

Flexible pumping system. Add a pump, or switch to larger pumps, and double, triple, even quadruple the pumping system's speed and capacity.

Flexible casting. Cast a single large mold or many small ones; add such accessories as arc hot-topping equipment in ports already provided.

Flexible accessories. All necessary accommodations for a sampler, immersion thermocouple, optical sight tube, vacuum throttling valve, interlock valve for charge addition, or any other accessories you want to add.

For more details on this flexible CEC induction melting furnace send for Bulletin 4-35.



Pumping systems are interchangeable: 1 or 2 KS-2000 (shown here), 1 or 2 KS-4000, or one KS-16,000.

Consolidated Electrodynamics
Rochester Division, Rochester 3, N. Y.
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OFFICES IN PRINCIPAL CITIES THROUGHOUT THE WORLD

Choosing Tool and Die Steels for Hot Work

Digest of "Tool and Die Steels for Hot Working Operations", by E. Johnson, *Alloy Metals Review*, High Speed Steel Alloys Ltd., Vol. 8, June 1956, p. 2-10.

THE PRINCIPAL alloying elements in hot die steels are chromium and tungsten. Other elements, such as silicon, molybdenum, nickel and vanadium, are frequently added to impart certain desired properties. These steels harden considerably when cooled in still air, but quenching is necessary to develop maximum hardness. They are designed to resist deformation, cracking and wear at elevated temperatures, and they deform only slightly on hardening and tempering.

No single hot work steel is superior for all applications and the technical literature lists several hundred analyses offered by various toolsteel producers. Some operations, such as hammer forging, require toughness primarily, while hot extrusion, for instance, demands maximum resistance to the effects of stresses and high temperatures. Choice rests on a thorough knowledge of operating conditions involved and of the various properties and characteristics of available steels.

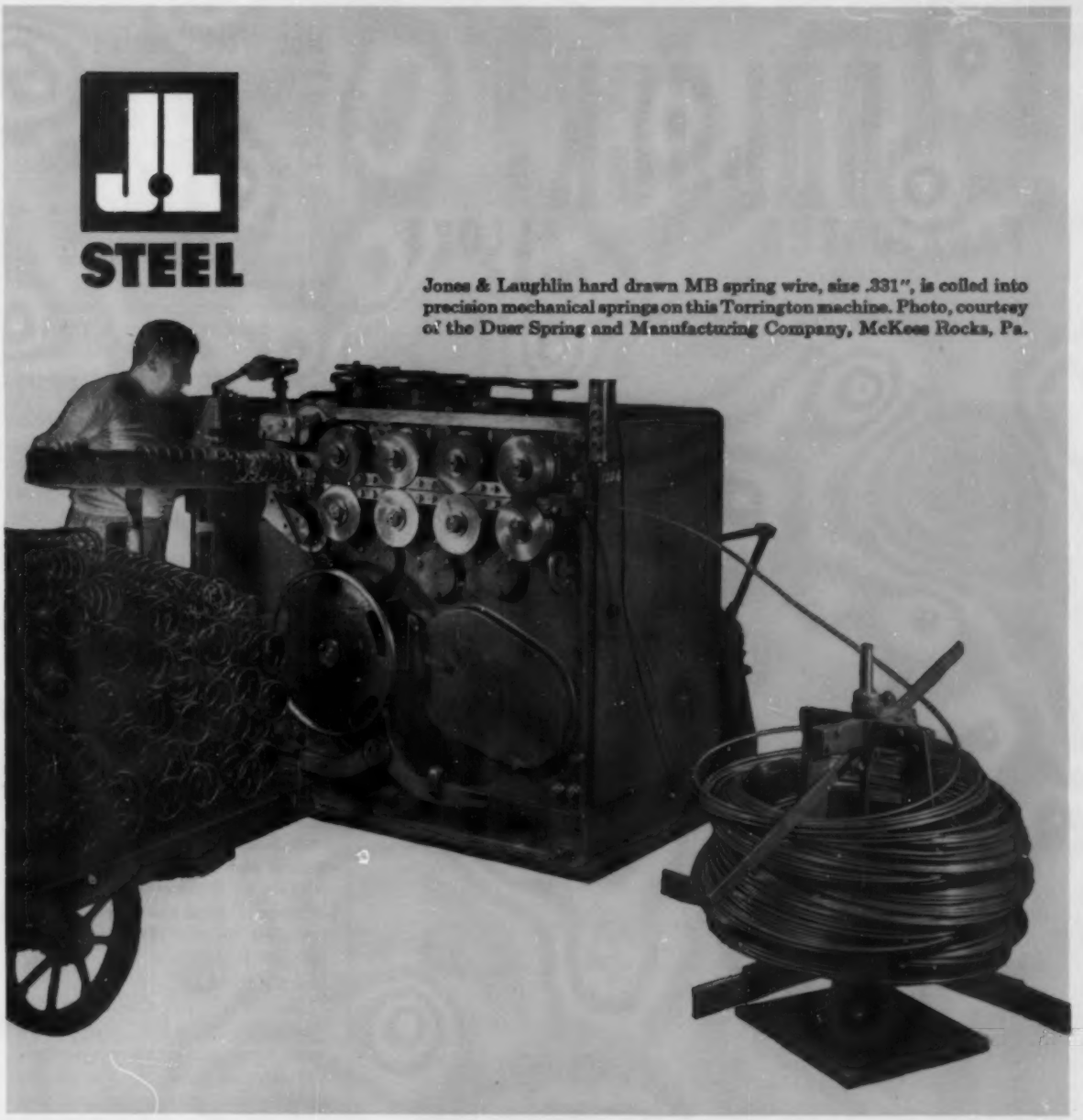
This class of steels is characterized by high strength and hardness at room and elevated temperatures, as well as good resistance to softening by prolonged heating. Other desirable properties are toughness, adequate hardenability, resistance to thermal shock and to oxidation and scaling, and ease of machining and heat treatment. Availability and cost are additional factors of practical consideration.

Carbon content exerts the primary influence on hardness and strength, since it is the amount of carbon in solution in the austenite at the time of quenching that determines the actual hardness, independent of alloy content. Carbon range normally is 0.25 to 0.55%.

Retention of hardness and strength at elevated temperatures is promoted by chromium, tungsten, molybdenum, vanadium and cobalt.

Good hardenability is provided by nickel, chromium, manganese and molybdenum.

Machinability of hot work steels in



Jones & Laughlin hard drawn MB spring wire, size .331", is coiled into precision mechanical springs on this Torrington machine. Photo, courtesy of the Duer Spring and Manufacturing Company, McKees Rocks, Pa.

SPECIFY J&L SPRING WIRE

. . . it's uniform, easy-to-work

Outstanding Uniformity of J&L wire helps you produce better springs . . . with faster production, fewer rejects. J&L spring wire assures uniform physical and dimensional characteristics combined with specific finishes to meet your requirements.

Jones & Laughlin exercises rigid quality control in every operation from ore mine to finished product. Every coil of J&L spring wire, be it famous Mastercraft, hard drawn MB or Electromatic oil-tempered MB, is thoroughly tested. Jones & Laughlin spring wire is tops in quality . . . competitive in price.

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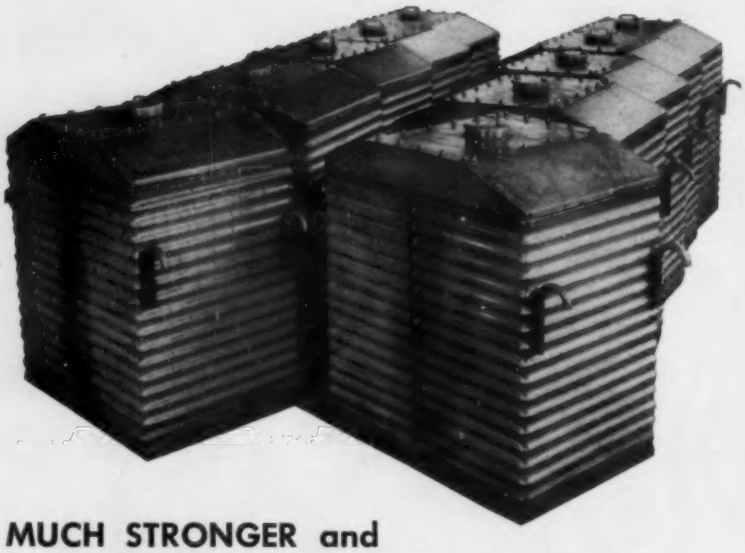
FABRICATED HEAT AND CORROSION RESISTANT ALLOYS



MUCH STRONGER and
MUCH LIGHTER process vessels
with ROLOCK'S new

CORRUGATED
WELDED CONSTRUCTION

All the advantages of lighter weight, rapid heat transfer, easier handling and lower over-all cost are inherent in this Rolock-perfected construction technique. Yet there is no sacrifice of strength or anticipated performance. In fact, vessels such as those shown above, of Type 316 Stainless Steel, can be expected to out-perform alternative designs in every way.

Skilled Rolock craftsmen, using specially developed equipment and technique, form the corrugated construction WITHOUT welding at the corners — a very important feature.

This is another example of the way in which Rolock designing and welded fabrication skills can help you meet new or unusual equipment needs. Always consult us first.

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ROLOCK INC., 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

JOB-ENGINEERED for better work
Easier Operation, Lower Cost

Hot Work Steels . . .

the annealed state is usually no problem and is, in general, better than that of the cold work tool and die steels because of lower carbon content. Parts such as die blocks often are machined in the fully hardened and tempered condition.

Popular in the U.S. are the tungsten-chromium-twin hot work steels, containing equal amounts of these elements in either 5, 7 or 12%. At present the 5 and 7% varieties appear to have little to recommend them over conventional hot work steels, but the type containing 12% has a number of advantages, despite lack of toughness. It has been used extensively in the die casting of brass and in extrusion dies for various copper alloys.

As-quenched hot work steels are too hard and brittle for service and must be tempered. The rate at which hardness falls during tempering is a function of the amount of alloy in the steel.

Nonhardenable or austenitic analyses are usually given a solution heat treatment, with a further aging treatment sometimes carried out to increase strength by precipitation of carbides. This may be accelerated by warm working where section and size permit. Also, cold working by hammering and peening of some austenitic types has been practiced. Success of this procedure depends largely upon the skill with which it is done.

Dies of cemented tungsten carbide (with up to 20% cobalt) have been used for extrusion of some high-alloy materials. Although the carbide has high cold and hot hardness, along with compressive strength, it is inherently brittle and has low resistance to thermal shock and to oxidation at high temperature. Modifications employing titanium carbides and also chromium carbides with nickel as a binder have been developed under proprietary names, as also have various combinations of sintered carbides in an infiltrated matrix of austenitic or other heat and corrosion resisting alloy steels. In general, these materials are available only in small sizes and are relatively expensive. As inserts, they may offer more useful and economical service.

Looking into the future, design of

for steel or non-ferrous metals

Now... 6 SPECIAL TITANIUM ALLOYS

Whatever your low-carbon titanium requirement, there's an ELECTROMET titanium alloy to suit your melting practice. ELECTROMET produces three standard grades of low-carbon ferrotitanium, each grade containing a maximum of 0.10 per cent carbon.

Of special interest to producers of high-quality forgings are the low aluminum and silicon contents of this alloy, which make ELECTROMET ferrotitanium specially suited for the production of forgings having good mechanical properties.

Silicon-titanium is available for adding titanium to either non-ferrous alloys or steels where the simultaneous addition of silicon is desired. Manganese-nickel-titanium is available for adding titanium to nickel-base high-temperature alloys. Aluminum-titanium is a special alloy for the titanium metal industry.

For additional information about ELECTROMET titanium alloys, please contact the nearest ELECTROMET office listed below.

ELECTRO METALLURGICAL COMPANY
A Division of
Union Carbide and Carbon Corporation
30 E. 42nd Street UCC New York 17, N. Y.

Offices: Birmingham • Chicago • Cleveland
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Electromet
Trade-mark
FERRO-ALLOYS AND METALS

ELECTROMET LOW-CARBON FERROTITANIUM

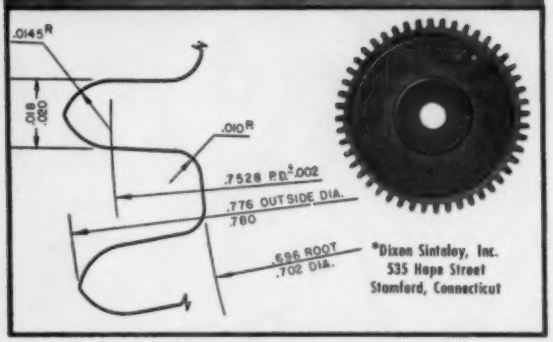
ELEMENT	20% Titanium Grade	50% Titanium Grade	70% Titanium Grade
Titanium	27-32%	50-55%	68-72%
Aluminum	0.15% max.	0.15% max.	0.15% max.
Silicon	0.10% max.	0.10% max.	0.10% max.
Carbon	0.10% max.	0.10% max.	0.10% max.
Size	2 in. x Down	2 in. x Down	2 in. x Down

OTHER TITANIUM ALLOYS

Silicon-Titanium		Manganese-Nickel-Titanium	
Titanium	40-50%	Titanium	46.5-48.5%
Silicon	45-50%	Manganese	6-8%
Iron	3.00% max.	Nickel	29-31%
		Aluminum	12.5-14.5%
Sizes: 2 in. x Down 1 in. x Down 20 Mesh x Down		Size: 2 in. x Down	

Aluminum-Titanium			
Regular Grade		High-Purity Grade	
Titanium	50 to 60%	Titanium	50 to 55%
Aluminum	40 to 45%	Aluminum	44 to 49%
Silicon	1.50% max.	Silicon	0.25% max.
Iron	2.00% max.	Iron	1.00% max.
		Carbon	0.15% max.
Crushed Size: ¼ in. x Down			

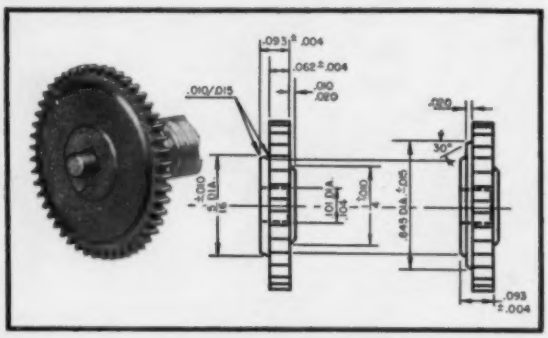
BRASS GEARS PRESSED FROM POWDER



. . . not only save money in manufacturing costs at the Marvel-Schebler Products Division of the Borg-Warner Corporation, but they are made dimensionally accurate to very close tolerances by its supplier* of brass powder parts.

Alternative methods of production involve scrap loss, machining time and expensive bar stock. On the other hand, as pressed and sintered from 80–20 leaded brass, the gear requires no secondary operations, involves no scrap loss, is accurate and durable.

The linear sequential timer in which this brass powder gear is used controls the operations of a leading home appliance in which dependability, long life and low cost are of major importance.



What can BRASS POWDER PARTS do for you?

For detailed information on the design, properties, production and application of brass and other nonferrous powder parts you should have a copy of our manual. It will give you 20 case histories of brass and nickel silver powder structural parts to assist in evaluating this means of production in terms of your particular needs.

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THE NEW JERSEY ZINC COMPANY
160 Front Street New York 38, N. Y.

Hot Work Steels . . .

tools and dies is a major factor in determining their performance in hot working operations. Much remains to be learned in this direction. Improved methods of cooling dies and mandrels to limit thermal effects might greatly extend their useful life span. And it should be kept in mind that the effects of thermal shock leading to heat checking often can be tempered by preheating dies before service.

ARTHUR H. ALLEN

Brittle Failure of Bronze Welds

Digest of "Brittle Failure of 'Bronze' Welds", by G. E. Morton, British Cast Iron Research Association, *Journal of Research and Development*, Vol. 6, October 1956, p. 403-408.

A SERIES of cast iron plates, welded with silicon bronze filler rod, were too brittle to machine. Since bronze welding using this type of filler rod is regarded as an extremely successful method of joining cast irons, an examination of the welds was made to isolate and determine the cause of failure.

Two similar filler rod analyses were used of the following composition: 60% Cu, 37% Zn, 3.0% Sn, 0.30% Si and traces of lead, iron and manganese. A microscopic examination of the brittle welds revealed similar microstructures. A notable feature was a band of material adjacent to the weld junction. The presence of graphite flakes extending from the parent metal into the weld metal indicated that considerable diffusion of some of the weld metal constituents into the original iron surface had taken place. Hardness traverses showed the layer at the weld junction to be substantially harder than either the weld metal or the base iron. There was no doubt that this hard layer was responsible for the brittle welds.

An X-ray analysis across the weld junction showed that a solid solution of some element in iron was present at the interface of the iron and the weld metal, and that the lattice parameter was reduced in this region. It was suspected to be

silicon, since silicon is known to be a lattice contractor.

A number of different rods containing varying amounts of silicon were used to weld a number of cast iron samples. All welds made with rods having more than 0.2% Si contained the hard layer, indicating that diffusion into the iron was very pronounced. Some back diffusion of iron into the weld metal was also apparent.

A similar layer was produced on steel samples welded with various bronzes. It seemed probable that immersing very thin sheet steel in molten silicon bronze would result in a sample layer suitable for chemical analysis. A 16-gage mild steel sheet was immersed in silicon bronze containing 0.5% Si at 1740° F. for 1½ hr. and then examined. This sample could not be cut with a hacksaw because its surface hardness was Rockwell C-38. A microscopic examination showed hard layers at each surface with an unchanged core. A chemical analysis showed an increase in silicon content from 0.30% to 1.96% as a result of immersion. A surface spectrographic analysis indicated very high silicon – greater than 5%.

A bar of steel was immersed in the same alloy for 6 hr. The depth of alloy at the surface was found to be 0.015 in. and the silicon content had increased from 0.19% to 5.04%. A sample of cast iron similarly treated showed an increase of silicon content from 2.22% to 6.54%. Further experiments indicated that the depth of the layer increased with increasing bath temperature.

From this work it was concluded:

1. The brittle welds in cast iron resulted from a brittle layer of iron-silicon alloy of high silicon content at the weld junction.

2. The thickness of the hard alloy increases with the length of time at welding temperatures; therefore, heavy welds are prone to brittleness.

3. The welding temperature will greatly affect the thickness of the brittle alloy layer since diffusion rates increase with increasing temperature.

4. Since the silicon of the filler rod is the source of trouble it should be sufficient only to deoxidize and promote fluidity of the weld metal. For cast iron welding 0.1% Si is a suggested maximum for filler alloys.

H. J. Nichols

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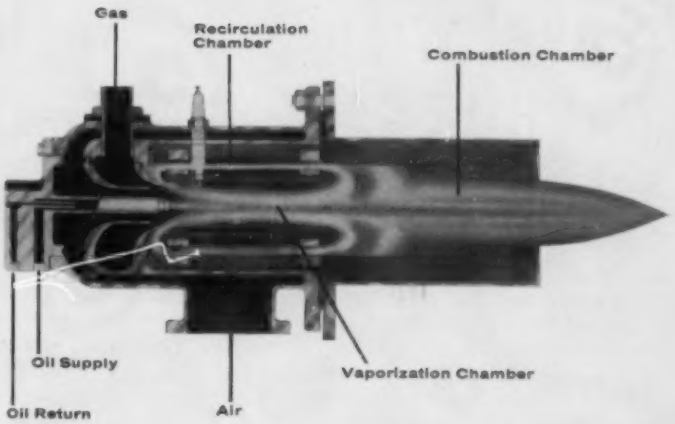

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Ladle Additions Enhance Properties of Castings

Digest of "Ladle Additions to Grey Cast Iron for High Duty Parts", by C. R. van-der Ben, *Alloy Metals Review*, High Speed Steel Alloys Ltd., Vol. 8, September 1956, p. 2-6.

FREQUENTLY a production gray iron foundry is faced with the demand for limited quantities of special-purpose iron castings requiring somewhat higher strength and toughness properties. These must be supplied, often on a small scale and perhaps intermittently, without undue interference with normal production operations.

Treatment of irons in the ladle during tapping is common practice, and many additives are available for a variety of purposes. Some effects can be realized only by late additions, or "inoculation" as it is popularly called, because the effects diminish with time of holding the molten metal after treatment. Ladle additions of either cold or molten alloy or a combination of alloys are a ready solution to the problem, providing a suitable "base" iron is available. With the low-strength base irons and high-phosphorus melts, there are limitations on what can be done by ladle additions, but a well-suited base analysis might be the following:

Total carbon	3.20 to 3.30%
Silicon	1.40 to 1.60
Manganese	0.70 to 0.90
Phosphorus	0.20 to 0.30
Sulphur	0.08 to 0.12

The lower silicon content would be preferable with the higher carbon and a proportion of the silicon, perhaps 0.15 to 0.20%, could be made as a ladle addition, provided pouring temperature is in the range of 2370 to 2460° F.

Among the alloy additions frequently employed for high-duty irons is a combination of nickel shot and crushed 70% ferromolybdenum. To attain a minimum tensile strength of about 45,000 psi. in a 1.2-in diameter test bar, an addition of 0.5% each of nickel and molybdenum is needed. If the carbon and silicon contents of the base iron are both above the upper figure of the range listed previously, then about 0.1% more of each alloy may be necessary. Increasing the nickel to 1% and molybdenum to 0.8% will give a minimum tensile of 51,500 psi. in a test bar, compared with 40,000 psi. in the base iron.

Control is essential in making the additions, both as to weight and composition of the alloys used, and in the quantity of the base iron. The latter can be determined accurately by knowledge of ladle capacity at marked depths or by suspension from a scale attached to the crane hook during tapping.

Effect of the alloy additions on the microstructure of the iron is to refine the graphite and to render the pearlite in the matrix more sorbitic. It is essential that, in view of the amount of cold alloy materials added to the molten metal, a high tapping temperature be maintained — on the order of 2550 to 2640° F.

Using a similar technique, suitable ferro-alloys are introduced to a base iron at the cupola spout — for

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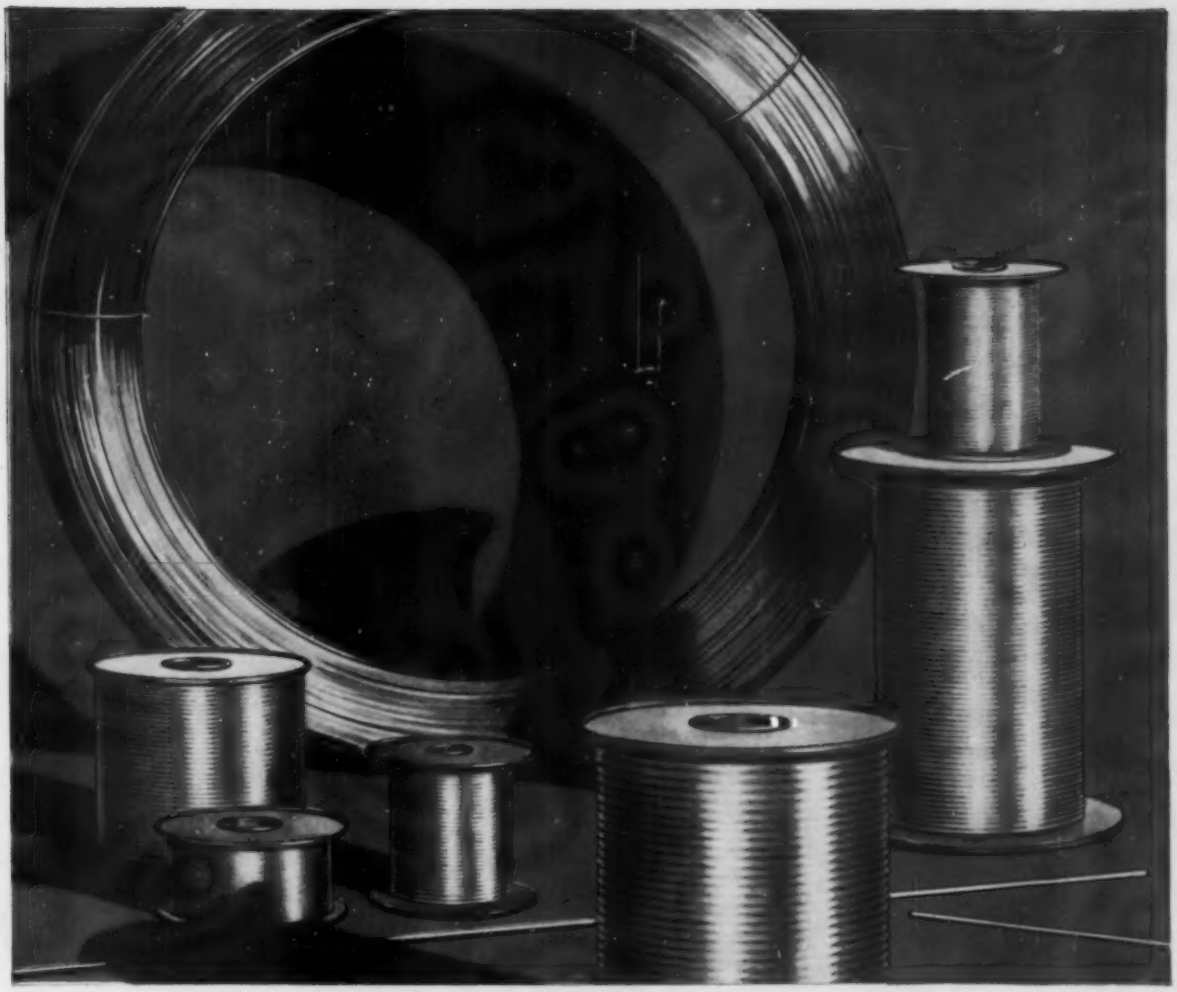

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Ladle Additions . . .

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If it is not desired to raise alloy content, the carbon of the final metal can be lowered by incorporating quantities of steel scrap in the crucible charge. By thus further reducing the carbon and raising the nickel and molybdenum contents, or a combination of the two, tensile strengths can be boosted still further, and toughness improved. In this instance, however – particularly if the carbon has been reduced to 3.0% or below thereby increasing solidification shrinkage and reducing fluidity – changes in casting and feeding technique will likely be necessary to produce sound castings.

ARTHUR H. ALLEN

Hydrogen in Steel

Digest of "The Significance of Hydrogen in Steel Manufacture," by K. C. Barraclough, *Murex Ltd. Review*, Vol. 1, No. 13, 1954, p. 305-348.

EARLY SAMPLING of liquid steel was concerned with the collection and analysis of the gas escaping during solidification and cooling of the metal. In one apparatus the gas evolved was collected in a deflated balloon and subsequently analyzed. A more recent device incorporates a sample mold with a ground upper face on which a top plate carrying a closed tap is clamped immediately after the mold fills with liquid steel. The author's method gives results comparable with the above devices and simplifies the sampling technique. A notched pencil mold similar to the mold used for preparing Carbonalyzer samples is used, the space between notches containing the individual steel samples. The steel sample is taken from the fur-

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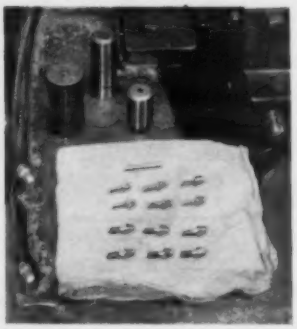
VULCAN Special Vanadium used for cold heading dies that are tough enough to produce slotted Nickel terminal screws at H. M. Harper Company, Morton Grove, Illinois.



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Hydrogen in Steel . . .

nace in a sample spoon, the slag carefully skimmed off the top of the metal, a small amount of aluminum wire added and the mold then filled with clean steel. If any slag enters the mold the sample is discarded. After 3 to 5 sec. the excess liquid steel in the head of the mold is poured off, and the pencil sample quenched in cold water. The sample is then transferred to a cold-box containing solid carbon dioxide. The rapidity of quenching and the necessity of obtaining a sample free from slag accounts for the superiority of this method over other pencil test procedures.

In the earliest survey of basic electric arc steel, the hydrogen content varied considerably from heat to heat. The hydrogen content at the end of the boil was usually lower than at the end of the heat. The increment between the end of the boil and tapping the furnace was lower when limestone, rather than burnt lime, was used for making the final slag. Moreover, if the burnt lime was held in the shop for some time before being used, the finished heat would have a higher hydrogen content.

In the author's works, careful control of the delivery and storage of the burnt lime makes possible the use of lime having an average moisture content of only 0.5%. This step, together with the preheating of alloy additions, reduces the hydrogen content on tapping by about 2.0 ml. per 100 g.

An analysis of many heats in the basic electric arc furnace shows that carbon steels in general are lowest in hydrogen, followed closely by alloy steels. In the stainless steels the straight chromium ferritic types (13 to 20% Cr) contain considerably more hydrogen than low-alloy steels, while the austenitic stainless steels (18 Cr, 8 Ni) have the highest hydrogen contents of any of the steels.

Carbon and low-alloy steels melted in a basic lined high-frequency furnace compare favorably in hydrogen content with steels melted by the basic electric arc process. With stainless steels, however, the basic lined high-frequency furnace is capable of producing heats with lower hydrogen

than the arc furnace. The atomization of atmospheric moisture in the arc is the probable reason for this. Heats obtained from the acid open-hearth furnace contain slightly less hydrogen than those encountered in basic processes.

When the furnace is tapped oxidation of the liquid metal surface occurs. One of the elements oxidized is believed to be hydrogen. This would explain why the hydrogen content of the steel in the ladle is lower than in the furnace. Steel collected in newly bricked or patched ladles will pick up additional hydrogen.

Steps which can be taken to insure low hydrogen content are:

1. Charge only dry slag-making materials during the period when the steel is deoxidizing.
2. Use a high carbon at melt and an active oxidizing slag to give a vigorous boil.
3. Use only dry ladles and molds.

The effect of hydrogen on steel may be considered from two points of view – its effect on the solidification of the steel, and its effect on the solid steel.

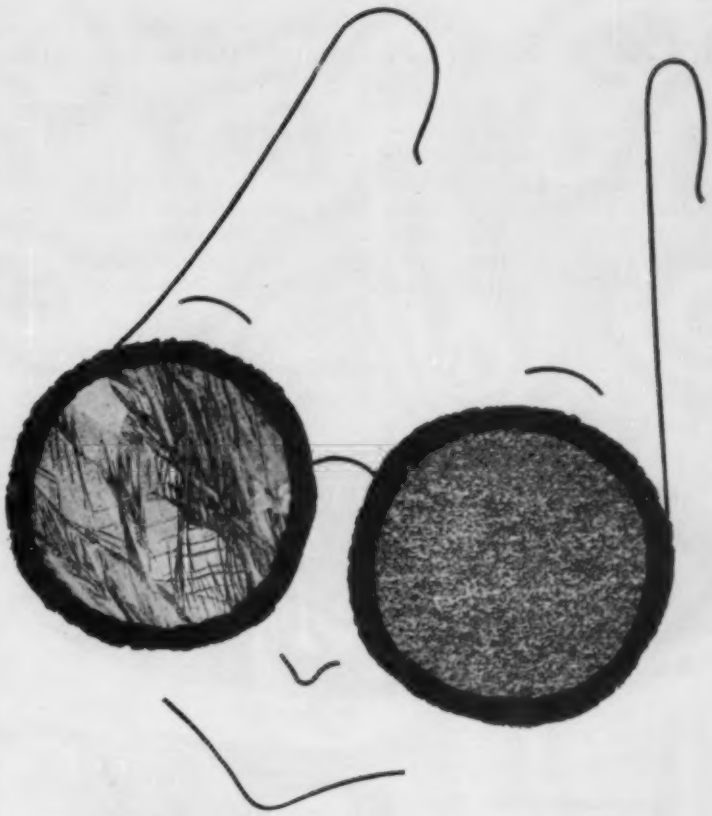
Sound fully killed steel ingots contain a limited amount of hydrogen. Greater amounts produce porosity and wildness, as shown in the following tabulation:

Steel	Hydrogen Content*	
	Porous Ingots	Wild Ingots
Carbon	6.5 - 8.5	> 8.5
Low-Alloy	7.0 - 9.0	> 9.0
Stainless		
Chromium	10.0 - 12.0	> 12.0
Austenitic	12.0 - 14.0	> 14.0

*Ml. per 100 g.

Even if the hydrogen content of a heat is within the range which should give sound ingots, in some instances it may still produce porous or even wild ingots. Generally this happens when another gas is liberated with the hydrogen during solidification, but it can usually be prevented by adding a small quantity of aluminum which insures complete deoxidation and fixing of any nitrogen. Hydrogen pickup during teeming may result in unsound ingots. Damp head boxes or damp cement between the headbox and the mold may also cause unsoundness in a steel ingot.

In solid austenitic or plain chromium steels little effect of hydrogen



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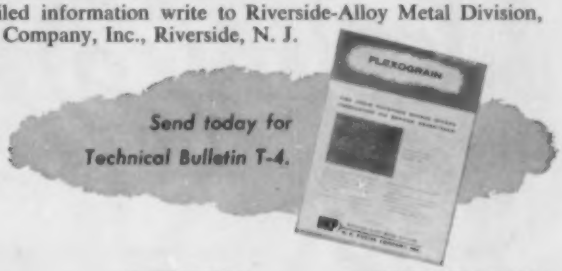

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Hydrogen in Steel . . .

on the properties of the steels is evident provided the ingot is free from porosity. In carbon or low-alloy steels, however, the effects are very noticeable, particularly the adverse effect of hydrogen on the ductility. Separate investigations show that the drop in reduction in area is a linear function of the hydrogen content. For a 3% Cr-Mo steel at tensile strengths down to, and up to, 115,000 psi. there is an increase in the embrittlement. At 115,000 psi. the embrittlement is at a minimum. Thus it appeared that the tempering temperature of 1240° F. is an optimum treatment for this class of steel. Prolonged tempering at 1240° F. produced spheroidization.

Transverse and radial tests show lower ductility than longitudinal tests without hydrogen present, but the rate of decrease of ductility with increase of hydrogen content is not so rapid. However, if the radial and transverse properties of large forgings are not to be adversely affected, then the hydrogen content at the center of the forgings should be maintained below 2.0 ml. per 100 g. Two bars of 3% nickel steel, one forged and the other case rolled from the same cast, showed similar embrittlement effects.

The embrittlement effect of hydrogen is not significant on bars up to about 6 in. diameter. This is because the normal manufacturing processes are sufficient to reduce the hydrogen content to below 2 ml. per 100 g. Embrittlement is not as serious as hairline cracks or flaking produced by hydrogen. The embrittlement can be removed by heat treatment. The occurrence of "flakes" is more prevalent in alloy steels – nickel steels are most susceptible to flaking. A standard practice at the author's works when rolling 3% nickel steel in billets up to 6 in. diameter is to cool them by stacking them hot in cooling pits as a safeguard against the formation of hairline cracks and flakes. Further experiments with the 3% nickel steels showed that suitable heat treatment, namely transformation at 840° F. followed by a full softening treatment at 1200° F. produces a billet without any hairline cracks.

The simplest means of reducing the hydrogen content of solid steel is by diffusion. Given the same temperature, the diffusion of hydrogen in ferrite is faster than in austenite. Thus, for rapid removal of hydrogen the steel should be heated to as high a temperature as possible and still remain ferritic. It has been calculated that for a 50-in. diameter forging, to reduce the hydrogen content at the center of the forging to half its previous level would take about 625 hr. assuming an original uniform hydrogen content of 8 ml. per 100 g. at a temperature of 1200° F. At the same temperature to reduce the hydrogen content to 1 ml. per 100 g. would take 2500 hr.

It is thus clear that any steps which can be taken to prevent hydrogen pickup in melting and casting are well worth while.

W. A. MORGAN

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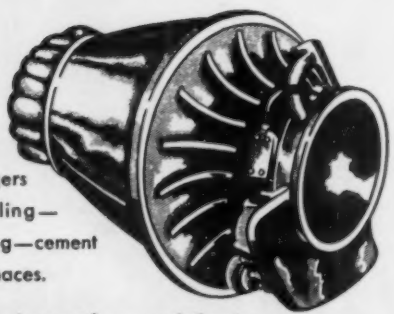

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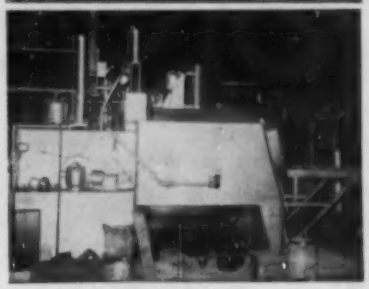

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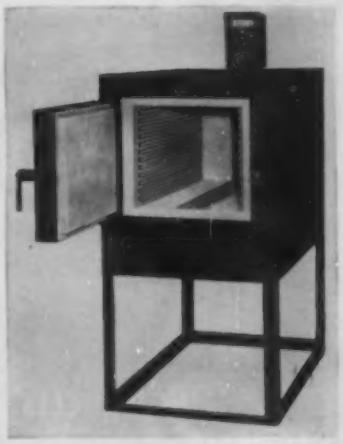

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WRITE FOR FREE LITERATURE, specifications and price list of Lucifer Furnaces in wide range of sizes—top loading and side loading types. Engineering advice without obligation. Write, wire or phone today.

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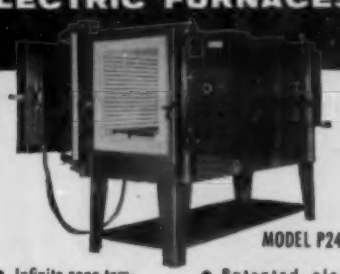
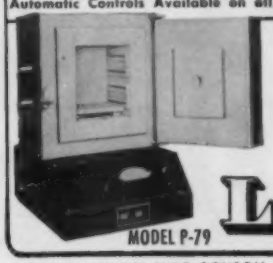
dyna-trol ELECTRIC FURNACES

MODEL NO.	FIRING CHAMBER (H.W.D.)	PRICE (300° to 2000°)	PRICE (400° to 2300°)
P46	4½"x4½"x6"	$90.00	$110.00
P79	6"x6"x9"	$205.00	$225.00
P918	9"x9"x18"	$480.00	$528.00
P414	14"x14"x14"	$525.00	$603.25
P124	12"x12"x24"	$715.00	$822.25
P818	18"x18"x18"	$775.00	$887.50
P136	18"x18"x36"	$1125.00	$1312.50

Automatic Controls Available on all Models



MODEL P2472-1



MODEL P-79

- Infinite zone temperature control.
- Zone temperature indication by Pyrometer Selector Switch.
- Automatic hold and cut-off instrument available.
- Patented element holders.
- Infinite variety of time-temperature curves obtainable.
- Rugged construction. Highest quality insulation used

OVER 40 STANDARD MODELS • WRITE FOR LITERATURE

L&L MANUFACTURING CO.
INDUSTRIAL DIVISION
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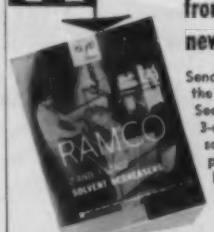
Q A METAL PARTS CLEANING PROBLEMS?

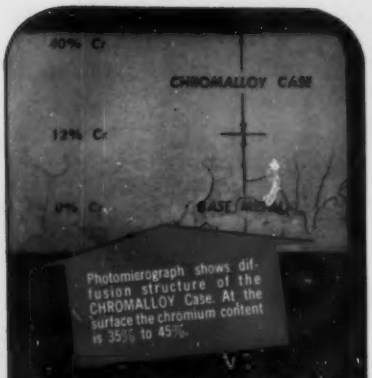
Get the answers RIGHT from RAMCO'S new BULLETIN!



Send for your copy of the Ramco Bulletin. See how Ramco 2- and 3-dip degreasers can solve your metal parts cleaning problems safely, efficiently, economically! Send today!

RAMCO EQUIPMENT CORP.
DIV. OF RANDALL MFG. CO., INC.
809 Edgewater Rd., New York 39, N.Y.

LIST NO. 128 ON INFO-COUPON PAGE 169


40% Cr
CHROMALLOY CASE
12% Cr
0% Cr
CASE
Photomicrograph shows diffusion structure of the CHROMALLOY Case. At the surface the chromium content is 35% to 45%.

CHROMIZING PROCESS COMBATS...

HEAT
WEAR
CORROSION

CHROMALLIZING diffuses chromium into the surface of iron and steel parts, providing the corrosion resistance of stainless steel and the wear resistance of chromium carbides. CHROMALLOY Case cannot chip, peel or flake.

Chromalloy Corporation is fully equipped for processing large or small quantities of parts. Engineering advisory service available.

FREE! TECHNICAL BULLETINS

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Telephone White Plains 6-0020

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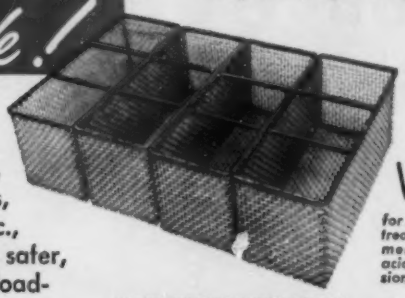
Custom Made!

all styles, metals, weaves ...any size, quantity!



Wiretex engineers Baskets, Muffles, Screens, Fixtures, Grids, Racks, etc., to insure easier, safer, loading and unloading; greater space saving, better draining and cleaning.

Call Wiretex for all your heat treating requirements to resist acid, heat, abrasion or exposure.

Wiretex mfg. co.

5 Mason St., Bridgeport 5, Conn.
Specialists in Processing Carriers Since 1932.

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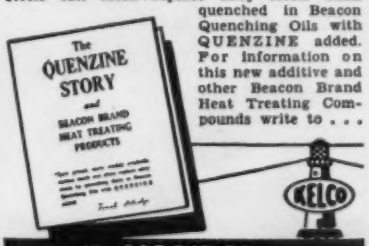
the QUENZINE STORY

Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .



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Grade "B"
FERROUS METAL PROCESSING

Eliminates . . .

Rust
Fire Hazards
Toxicity
Dermatitis
Degreasing

Write for free sample and brochure
Specify Grade "B"

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We are specialists in the designing, engineering and manufacturing of equipment for handling parts through heat treating, quenching, pickling and related operations. Let our broad experience serve you! We can supply baskets, trays, fixtures, carburizing boxes, retorts or furnace parts designed to meet your specific requirements.

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Stanwood Corporation
HEAT TREATING EQUIPMENT
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Taber Stiffness TESTER

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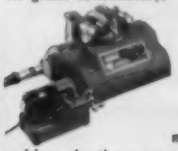

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Tests wear resistance of metal, plastic, paint, rubber, leather, paper, foil, etc. With average technical experience, anyone can make a scientific, comparative abrasion resistance test with this instrument.

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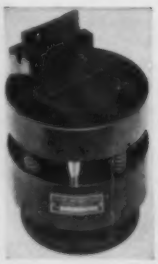
MULTI MOTION DIES* . . . .
FOR TEST SPECIMENS . . .



DL-1001
TENSILE TEST BAR
MPA STANDARD
10-51

- Tensile Bars
- Transverse Bars
- Green Strength
- Bushings
- Slugs
- Stepped Parts

Complete design facilities for dies or subpress units to press unusual shapes in lab presses.

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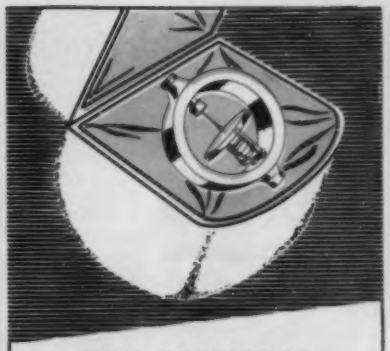

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Accurate force measuring and weighing equipment brings a top price in the industrial market and you who use this equipment pay the price willingly, because you have built your business on accuracy.

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NEW "A-B-C" BOOKLET AVAILABLE
The most practical handbook on force measuring system accuracy available today is yours for the asking. Write for it right away.

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SHORE SCLEROSCOPE

Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

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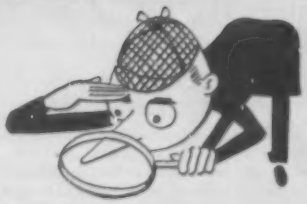

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LOOKING FOR USED EQUIPMENT?

This new service on used heat treating equipment is completely without obligation to you. To receive the latest availabilities just drop us a line requesting to be placed on our mailing list for a monthly digest. What are your production requirements?

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This free listing is yours at no cost. CHECK WITH HOLDEN FIRST. Proven MONEY MAK-ER PRODUCTS.

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NEW HAVEN, CONN. (STate 7-5885)

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Inspection Demagnetizing or Sorting PROBLEMS?

SOLVED with

MAGNETIC ANALYSIS MULTI-METHOD EQUIPMENT

Electronic Equipment for non-destructive production inspection of steel bars, wire rod, and tubing for mechanical faults, variations in composition and physical properties. Average inspection speed 120 ft. per minute.

Over 80 installations in steel mills and fabricating plants.

MAGNETIC ANALYSIS SPECIAL EQUIPMENT

Electronic Equipment for non-destructive production inspection of both non-magnetic stainless and high temperature steel bars and tubing—seamless or welded—as well as non-ferrous bars and tubing. Mechanical faults, variations in composition and physical properties are detected simultaneously. Average inspection speed 200 ft. per minute.

Over 30 installations in mills and fabricating plants.

MAGNETIC ANALYSIS COMPARATORS AND METAL TESTERS

Electronic Instruments for production sorting both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

MAGNETIC ANALYSIS DEMAGNETIZERS

Electrical Equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

MAGNETIC ANALYSIS MAGNETISM DETECTORS

Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

TRADE MARK

For Details Write:

MAGNETIC ANALYSIS CORP.

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"THE TEST TELLS"

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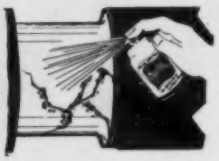
DYELINE INSPECTION PROCESS



Dyeline—a new two-stage inspection process for all non-porous materials. No skilled operator or expensive equipment necessary! Just spray Dyeline, follow with Dyeline Detector, and the exact location, type and extent of defects appear sharply and clearly on an opaque background!

No solvent required—water removes Dyeline immediately.

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ZIP SPEED LACQUER—Identifies all materials with a quick color-coding process.

ZIP RUST STOPPER #1 Protects metal parts for storage.

ZIP RUST STOPPER #2 Protects parts left in machinery for further processing; removes fingerprints.

ZIP PATTERN LAYOUT FLUID—Shows up scribed patterns strongly.

ZIP STENCIL INK—Quick drying—excellent on cartons and metals.

ZIP BELT LUBE—Prolongs belt life; promotes safety and speed.

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MERCOID® CONTROLS

TEMPERATURE PRESSURE LIQUID LEVEL

EQUIPPED WITH
SEALED MERCURY CONTACT SWITCHES
"The Contact That Never Requires Cleaning"

FOR OUTDOOR, INDOOR OR EXPLOSIVE ATMOSPHERES

Our engineers are at your service—send in your control problem or

Write for catalog No. 857

THE MERCOID CORPORATION
4211 Belmont Ave., Chicago 41, Ill.

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THE NEW

DERMITRON

NON-DESTRUCTIVE COATING THICKNESS TESTER

FAST—ACCURATE
COMPACT—PORTABLE
DIRECT-READING

- *Sorts Metals and Alloys*
- *For Metals on Metals*
- *Non-Conductors on Metals*
- *Metals on Non-Conductors*

You can now have 100% inspection of production of nearly any possible coating on almost any base—including the first and only accurate, direct readings of such combinations as zinc, cadmium, copper on steel; silver on brass; copper on zinc; anodizing on aluminum; organic coatings on non-ferrous metals — without the use of chemicals.

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for ALL Industrial Uses

- Degreasing
- Anodizing
- Pickling
- Plating
- Heat Treating
- Heavy Industrial Types

ANY SIZE AND SHAPE • ANY DUCTILE METAL

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THE C. O. JELLIFF MANUFACTURING CORP.

SOUTHPORT • CONNECTICUT

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ULTRASONIC

Thickness Testing from One Side

Rapid, Accurate, Non-Destructive

VIDIGAGE®

14" or 21" Cathode-Ray Screen with direct-reading scales between 0.005" and 2.5"; accuracy 0.1% to 1.0%.

AUDIGAGE®

Portable Thickness Testers for ranges from 0.020" to 4" or 0.060" to 12" of steel; accuracy up to 1.0%.

Detect Laminar Flaws and Lack of Bond

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Specializing in Ultrasonics Since 1946

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Solventol

ORIGINATORS OF DI-PHASE METAL CLEANING

DESIGNERS & BUILDERS OF SPECIALIZED METAL CLEANING EQUIPMENT

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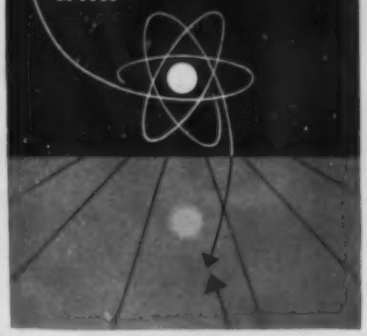
TECHNIC

equips you to Electroplate Precious Metals with



SCIENTIFIC PRECISION

Technic, Inc. equips you with controlled apparatus and electroplating solutions to maintain exacting standards and close tolerances. Typical benefits are the spectacular economies Technic effects in handling gold — where often electroplaters lose up to $60,000 or more of every $100,000 worth through outmoded equipment, inefficient methods and solutions.

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TECHNIC BIBLIOGRAPHY

Technic publications, authoritative in our field: "Electroplated Gold"; "Precious Metal Electroplating Data: Gold, Rhodium, Palladium, Platinum, Silver, Nickel"; "Electroplated Platinum"; "Electroplated Palladium"; "Electroplated Rhodium"; "Analysis of Gold & Gold Alloy Solutions".

Consult us without obligation, whether in respect to a new installation and electroplating solutions, or an existing system now in use. Write for Technic publications in your field of interest.

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Providence, R. I.
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Chicago Office—7001
North Clark Street

THE LARGEST ENTERPRISE OF ITS KIND IN THE WORLD

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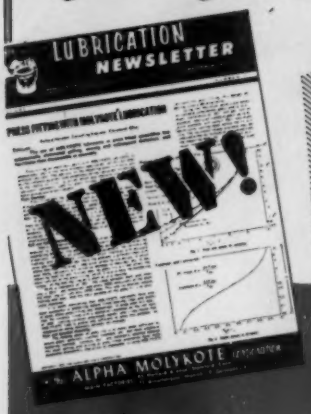
Engineering Data on MOLYKOTE® lubricants



- Being published regularly
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- "How-to" stories on tough lubrication applications
- Get on our mailing list TODAY. Write to

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Patent Pending

Accurate test specimens machined from sheet and plate materials .0005 to .500 in., in less than 3 min.

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Horse Plain Rd. • New Britain, Conn.

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the GENUINE BRINELL
HARDNESS TESTING MACHINES
made by the Alpha Co. of Sweden and available from our stock at New Rochelle

Never approached in ACCURACY AND CONSTANCY of calibration . . . at the standard 3000kg test load: . . . maximum error plus or minus 2½ kg

Write for Bulletin No. A-18

GRIES INDUSTRIES, INC.
Testing Machines Division
NEW ROCHELLE 2 N Y

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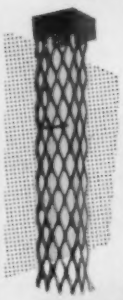
there's a *Glo*-QUARTZ* IMMERSION HEATER for Your Every Heating Requirement



- INSTANT HEATING
- SHOCK-PROOF
- AVAILABLE IN ALL VOLTAGES —WATTAGES, ONE AND THREE PHASE

Available from your Electroplating Distributor

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ELECTRIC HEATER CO., INC., Willoughby, Ohio
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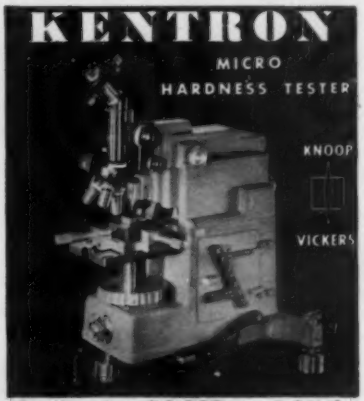
KENTRON
MICRO HARDNESS TESTER



Applies 1 to 10,000 gram loads
Write For Bulletin

Kent Cliff Laboratories Div.
The Torsion Balance Company
CLIFTON NEW JERSEY

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BRIGHT GOLD
Mirror-bright finish in any thickness directly from the bath.
Patent Pending

SILVREX BRIGHT SILVER
Crystal-clear solution that produces mirror-bright deposits.
Patented

BRIGHT RHODIUM
Brilliant, fine-grained, non-tarnishing deposits.

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Restores contaminated cyanide plating baths to full, trouble-free operation.
Patented

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Non-dusting — safest and easiest to use.

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Only rhodium electroplating process that yields extra heavy compressively stressed deposits.
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Sel-Rex
SEL-REX CORPORATION
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Offices: Detroit—Chicago—Los Angeles

Complete installation and servicing on all precious metals processes.

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Since 1923

Specialists in All Phases of METAL CLEANING EQUIPMENT

- DEGREASERS • AGITATING WASHERS • PICKLERS
- PHOSPHATIZING WASHERS • ALKALINE WASHERS
- FLOW COATING SYSTEMS • "SPOTLESS" DRYERS
- OVENS • ULTRASONIC CLEANING EQUIPMENT

We will be happy to send a sales engineer to help you with any metal cleaning equipment problem. Complete information on request.

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CIRCO EQUIPMENT COMPANY

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SPECIALISTS IN THE FIELD OF

Die Castings

SINCE 1922

Aluminum and Zinc

THE HOOVER COMPANY
Die Castings Division
North Canton, Ohio

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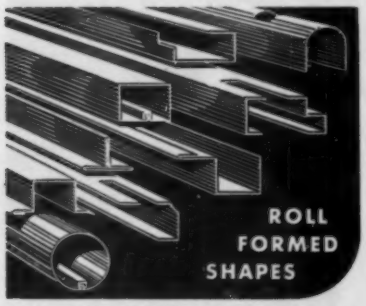

Reduce your assembly problems and costs. Our shapes continuously formed, with high degree of accuracy, from ferrous or non-ferrous metals. Write for Catalog No. 1053.

ROLL FORMED PRODUCTS CO.

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3761 OAKWOOD AVE. • YOUNGSTOWN, OHIO

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New pocket size
Ferritic **ELCOMETER**

Answers need for rapid testing. New precision instrument shows directly on scale the per cent of Ferritic content of weld, replacing time-consuming, destructive laboratory analysis. Enables you to make rapid, on-the-spot, nondestructive tests for iron content.

Accurate readings in all positions. Needle locking device assures correct readings. Balanced in all planes. Sturdily constructed. Comes in tough leather case. Fits in pocket.

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FERRO CORPORATION

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SOLUTIONS TO YOUR METAL TREATING PROBLEMS! . . . .

SWIFT BLACK

Activanium Blended— Positive blackening **BLACK** of every ferrous metal and alloy!

NOT GRAY
NOT FADED
NOT MOTTLED
BUT RICH, DARK, UNIFORM

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For a tougher, more durable case!

SWIFT HEAT

Liquid Salt Baths—
Temperature range 300° to 2500° F.
. . . no decarburization!

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An emulsifiable rust protective, effective even under humid conditions.

METAL CLEANING PICKLING and PLATING COMPOUNDS

Acid additives, brighteners, bright dips and chromate conversion coatings!

Send today for literature and technical data sheets.

THE Swift INDUSTRIAL CHEMICAL CO.
Canton, Connecticut

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• All Analyses
• Coated, Straightened
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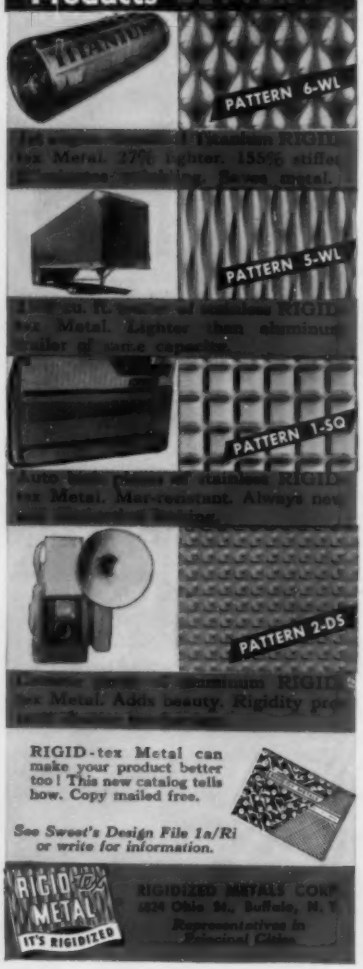

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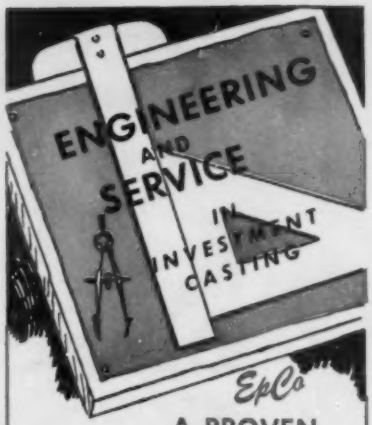

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Composition of Carbides in Low-Alloy Steels

Digest of "Some Experiments on the Composition of Carbides in Low-Alloy Steels", by J. E. Bowers, *Journal* of the Iron and Steel Institute, Vol. 183, July 1956, p. 268-274.

A STUDY of the effects of transformation temperature and of tempering on the composition of carbides in low-alloy steels is reported by the British Iron and Steel Research Association. It includes more information than previously available regarding the distribution of the alloying element between the carbide and the ferrite phases in the steel.

Six steels were used, containing 0.22 to 0.51% C, less than 0.30% Si, less than 0.08% P, and less than 0.03% S. Steel No. 1 contained 1.63% Mn; No. 2, 1.45% Mn and 0.26% Mo; No. 3, 0.78% Mn, 0.97% Cr, 0.33% Ni and 0.06% Mo; No. 4, 2.42% Mo, 0.32% Ni, and 0.31% Cr; No. 5, 2.97% Cr (with 0.51% C); and No. 6, 3.03% Cr (with 0.22% C).

Austenitized samples were completely transformed at various temperatures; the time given at each temperature was determined dilatometrically from the isothermal transformation curve. The carbides were extracted from these samples by anodic solution of the ferrite in 5% HCl, and analyzed for metal contents chemically and by X-ray. On the two chromium steels (No. 5 and No. 6) similar tests were also made on samples quenched from 1740° F. and tempered for various times at various temperatures between 750 and 1290° F.

In the manganese steels (No. 1 and No. 2) the manganese content of the carbide phase was very low in samples transformed isothermally below 950° F. to bainite. In samples transformed at temperatures between 950 and 1200° F. to pearlite, the ratio of manganese to manganese plus ferrite in the carbides rose gradually with higher temperature to about 13%, with the structure remaining that of Fe_3C. In steel No. 2 the molybdenum content of the carbide remained very low even when transformed at 1200° F.

In steel No. 3, the carbides in samples transformed below 900° F. were almost pure cementite, but when transformed at about 1000° F.

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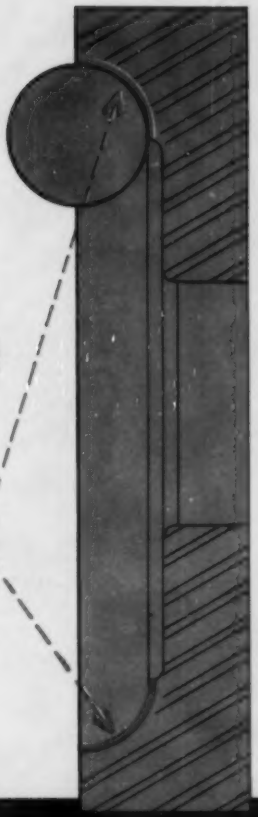

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Carbides in Steel . . .

the metal content of the carbides was about 7% Mn and 9% Cr.

In the molybdenum steel (No. 4) austenitized at 1920° F. transformation was too slow between 850 and 1100° F. to reach completion for these tests. Carbides produced by transformation below 850° F. contained very little molybdenum and had the structure of Fe_3C. Those produced by transformation to pearlite between 1100 and 1290° F. contained about 30% Mo and had the structure of Mo_2C.

In the chromium steels (No. 5 and No. 6) transformation below 850° F. gave bainite, with very little chromium in the carbides. When isothermally transformed above 930° F., in the pearlite range, the carbides formed had the structure of Cr_7C_3 and contained over 40% Cr. When these quenched chromium steels were tempered, the carbide formed at as low a tempering as 750° F., contained some chromium, and tempering at higher temperatures gave progressively more chromium in the carbide. This was true also of longer time at a constant tempering temperature. Carbide having the Fe_3C structure could contain as much as 20% Cr, and with further tempering carbide having the Cr_7C_3 structure appeared. This carbide contained as much as 66% Fe, and gradually replaced the Fe_3C type. The change was more rapid at higher temperatures. The carbide contained more chromium after prolonged tempering after isothermal transformation to pearlite at the same temperature. The maximum value found in the carbide from steel No. 5 with 0.51% C was about 50% Cr, and in the carbide from steel No. 6 with 0.22% C, about 70% Cr. Even when the isothermally transformed samples were tempered for 30 days, their carbides did not attain the high chromium contents of the quenched and tempered samples, presumably because of the difficulty of diffusion in the coarser structure.

These results confirm previous conclusions that Fe_3C is formed when low-alloy steels are transformed to bainite, but with long transformation times in the upper bainite range there is some segregation of chromium and manganese into the carbide. If sufficient alloy is present, the alloy carbide is formed when the steel is transformed to pearlite; but otherwise the carbide is cementite with some alloy content, which becomes higher as the transformation temperature is raised.

Previously it has been suggested that the occurrence of Cr_7C_3 instead of Fe_3C on tempering 3% Cr steel above 930° F. arises from a nucleation entirely independent of preexisting Fe_3C. The present author proposes that when the chromium content of cementite reaches 20%, giving the formula $Fe_7Cr_2C_3$, it becomes unstable and decomposes to $Fe_5Cr_2C_3$ plus 2 Fe. The latter trigonal carbide contains 24.8% Cr, in fair agreement with the experimental observations if some diffusion of chromium into carbide during the reaction is assumed. The evidence now available is insufficient to determine which hypothesis is most likely to be correct.

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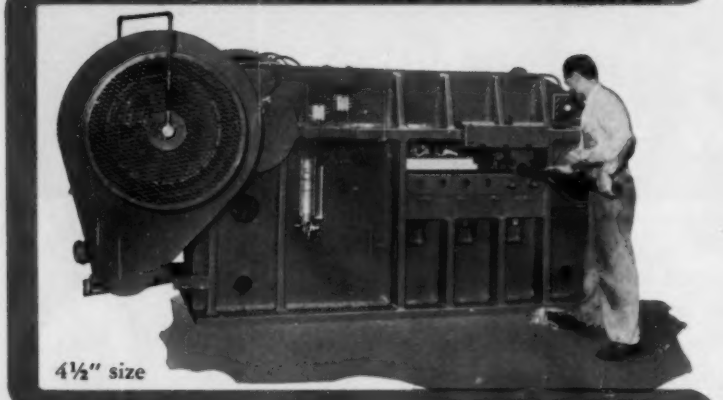

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Processing With Supersonic Energy

Digest of "Processing With Supersonic Energy", by Carl E. Meinheit, *Sylvania Technologist*, Vol. 9, July 1956, p. 89-94.

RECENT DEVELOPMENTS in the field of ultrasonic energy reveal that its application can greatly improve numerous industrial processes such as cleaning, degreasing, machining, and soldering. In addition, ultrasonic energy can be utilized in measurement and analysis techniques such as in flaw-detection instruments, flow meters, and depth gages. The energy ranges in frequency from 20 kc. to 1 mc. and may be produced by mechanical or electrical methods.

In the majority of ultrasonic industrial processes the workpiece is submerged in a liquid in which a transducer is vibrating at its mechanical resonant frequency. The vibrations cause cavitation bubbles to form and collapse and the energy for the process is furnished by the collapsing bubbles. A typical illustration is ultrasonic machining.

In this process the workpiece is submerged in water and a tool vibrating at a high frequency is placed in contact with the surface to be machined. Water carrying a powdered abrasive is flowed between the tool and the workpiece. The vibrations cause cavitation bubbles to form and collapse. Their collapse propels the abrasive particles against the workpiece with great force eroding a hole of the shape of the tool. Tool wear is minimized by using a soft material such as cold rolled steel.

Another example is cleaning and degreasing. In this process the object is placed in a suitable fluid which is excited by ultrasonic vibrations. The vibrations cause localized scrubbing actions which are very effective in removing dirt and grease.

A third illustration is fluxless soldering. Ultrasonic energy at a frequency of approximately 20 kc. is applied to the molten solder causing cavitation to occur on the surfaces to be joined. This breaks up the oxide coating allowing the solder to wet the clean metal. This process has greatly facilitated the soldering of rapidly oxidizing metals such as aluminum. Furthermore, since all

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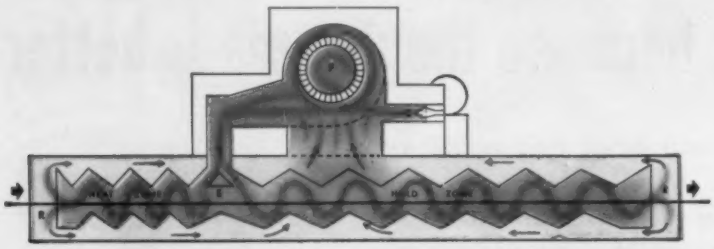

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PIONEERS AND STILL LEADERS IN RECIRCULATION

Supersonics . . .

metals can be soldered by this method it is finding widespread use for applications where the corrosive effects of a flux would be very detrimental.

The possible uses of ultrasonics are still in the embryo stage although it is presently being used in a number of commercial processes. However most of these are confined to processes where existing methods are unsatisfactory because existing equipment is uneconomical for applications requiring low unit cost. These costs will be reduced as more experience is accumulated and as the efficiency of the equipment is increased. B. TROCK

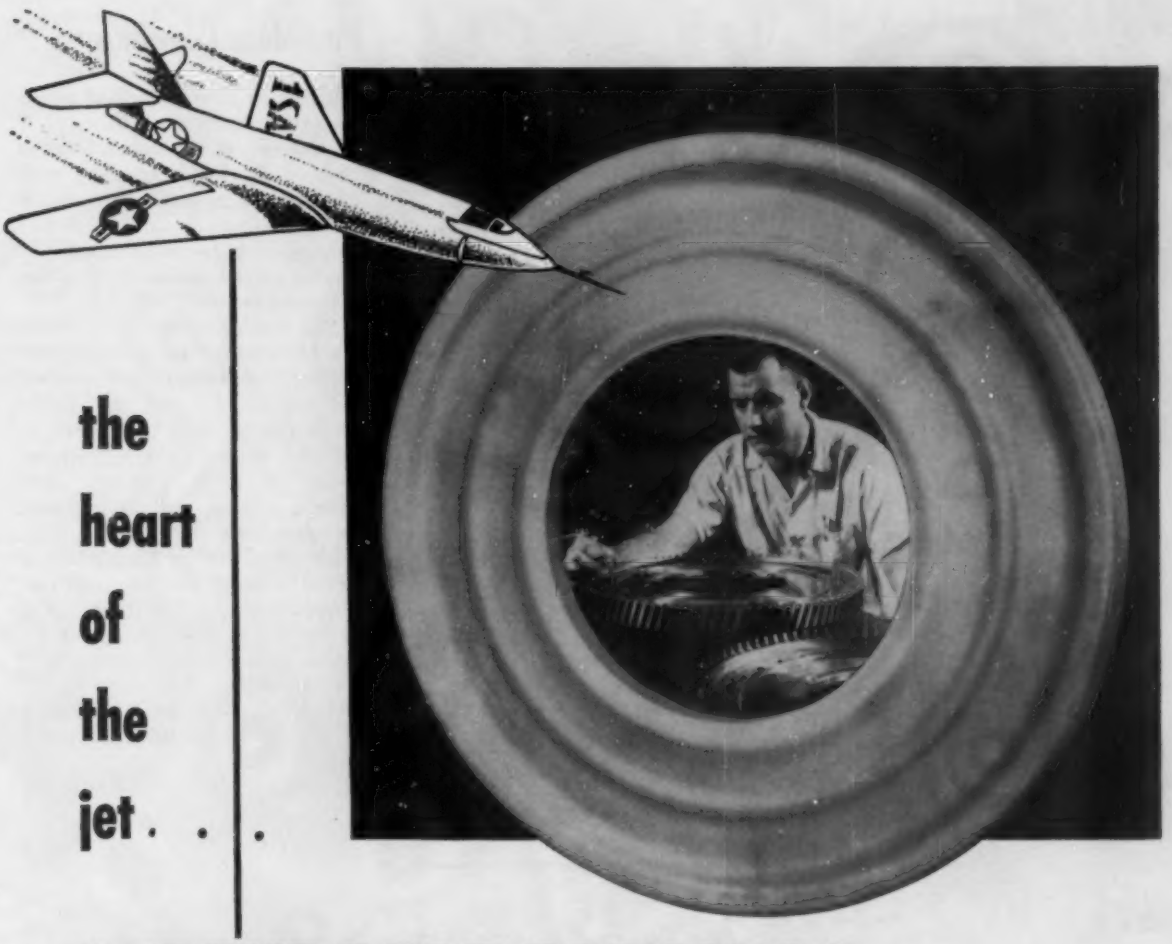
Punchless Drawing of Sheet Metal

Digest of "Deep Drawing of Sheet Metal by Friction Forces", by N. A. Maslennikov, *Vestnik Mashinostroyeniya*, May 1956, p. 59-63; translated and condensed in *Engineers Digest*, Vol. 17, September 1956, p. 366-368.

A SHORTCOMING of current methods for deep drawing thin sheet metal is that frequently several operations are required, with multiple dies and intermediate anneals. The explanation is that the system of forces effective in conventional deep drawing leads to the formation of a dangerous cross section in the transition zone where the radius of the drawing punch blends into its cylindrical shape. Excessive strain in this area, caused by tensile stresses, leads to cracking or breaking.

To overcome this deficiency, a new process has been devised for deep drawing sheet metal by means of friction forces. The essential feature of the process is a radical change in the system of forces acting during cupping in a closed die.

In conventional deep drawing, forces involved in the plastic deformation of the rim of the blank and for bending the material around the punch and die cannot be varied, since their magnitude depends exclusively on the drawability of the sheet or blank. The only forces which can be modified at will are the friction forces, which are in a direction opposite to the flow of metal, thereby



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Punchless Drawings . . .

opposing its deformation and giving rise to tensile stresses. However, if the direction of the friction forces is changed so that it coincides with the direction of metal flow, and if such forces are of sufficient magnitude, they can become active forces, causing not tensile but compressive stresses in the metal.

This change in the force system can be achieved by reversing the friction forces in the plane between the blank-holder and the blank, which can be done by inserting a suitable flexible friction element under the blank. Rubber, elastomeric plastics and some metals are adaptable to this purpose. With a flexible rubber friction element, a special drawing tool has been employed, involving a die body at the bottom of which is set a thin annular ring of rubber. The blank is placed over this and is surmounted by the die and a pressure sleeve, the entire assembly being carried in a suitable press.

The sketch shows the cross section of the tool with the addition of a

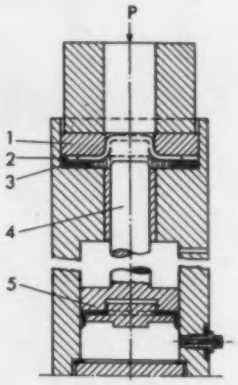

Diagram of Friction Drawing Tool

punch. The pressure P is transmitted through the die (1) and blank (2) to the rubber ring (3), drawing the blank by friction forces into the die hole. At the same time, a punch (4), operated by an oil or air-actuated piston (5) advances against the blank at a constant pressure, and also draws the metal into the die.

As pressure is transmitted from the sleeve, the rubber ring under compression moves in the direction

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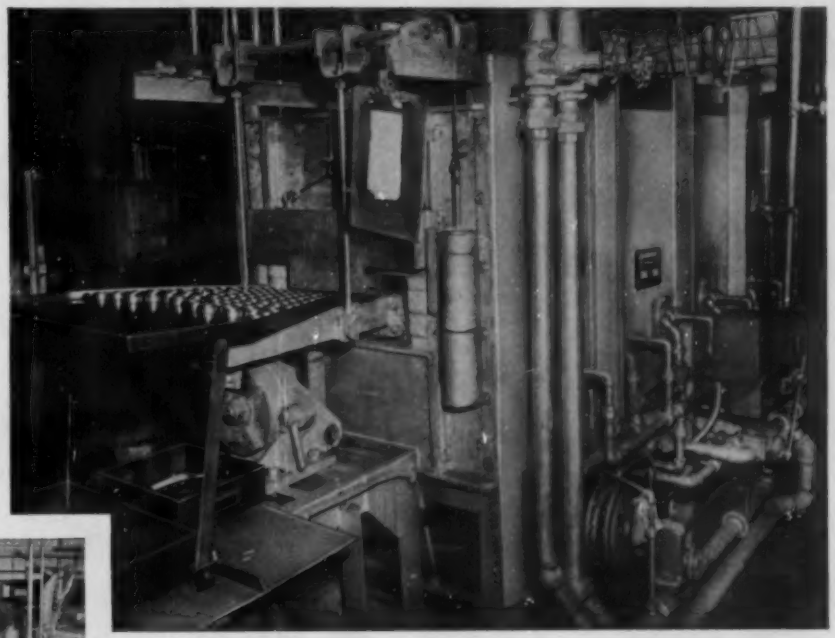
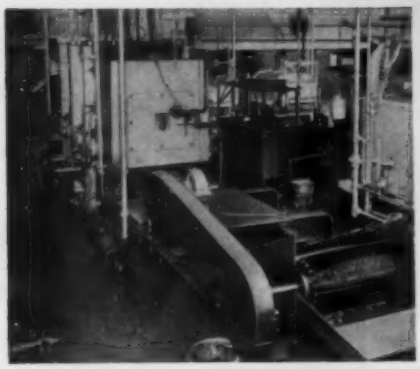


(1) Charge end of Stewart Reciprocating Hearth Furnace showing bearing races entering. Average output is 125 pounds per hour. S.A.E. 52100 steel is hardened to 65-66 Rockwell C. Nichrome hearth casting has been operating over 9 years.

(2) At discharge end, ball races are dropped into conveyer tank and quenched from 1540–1550 degrees.



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of least resistance, or inward into the die hole. Friction forces draw the rim of the blank in the same direction. Assuming sufficient force, by virtue of a certain specific pressure and friction coefficient between the rubber and the blank, the drawing or cupping operation actually will be performed by friction. When the load is removed, the rubber is released, the die returns to its initial position and the cycle is repeated.

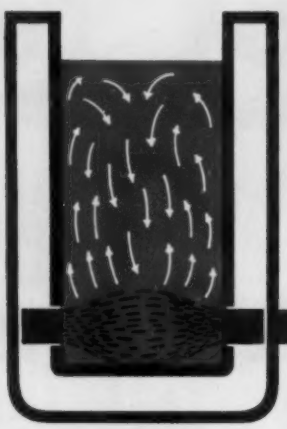
Initial tests were made on thin-gage circular blanks of aluminum alloy in a closed die. Preliminary work also was done on steel blanks, although results were inconclusive. It was found that hard rubber was the most suitable friction ring material. The ring must deform evenly throughout its entire thickness, this being insured by choice of optimum thickness in the ring.

Of particular importance is the correct lubricant, the object of which is to reduce the friction between the rubber and the die body and to create conditions of even deformation of the rubber layers across the thickness of the ring. Lubricants finally chosen consisted of 70% colophony and 30% castor oil for the contact surface between the rubber and bottom of the die body, 50% colophony and 50% castor oil between the blank and the die face, and pure colophony powder between the rubber and the blank.

With an increase in the initial diameter of the blank, the number of strokes or compressions of the rubber ring required to complete the draw increases. With a larger press load, for blanks of the same diameter and same material, fewer strokes are required. Depending upon the degree of slip between the rubber and the blank during each working stroke of the press, a definite deformation of the rim of the blank occurs and the rim contracts. Decrease in diameter of the rim develops in the first few strokes and then, as strain hardening progresses, deformation gradually diminishes and finally stops.

The operation can be supplemented with a punch, actuated hydraulically and coming up through the lower die body. This gives a better quality to the formed piece and adds a load which facilitates the action of the flexible friction element. Clearance between the punch and die must be several times that used on ordinary deep drawing work.

ARTHUR H. ALLEN



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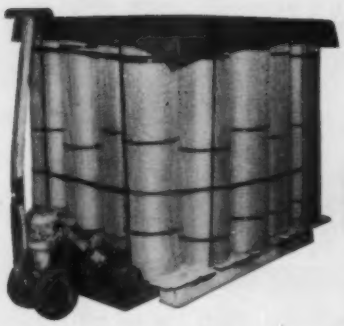
Prevention of Metallic Contact Corrosion

Digest of "Corrosion and Its Prevention at Bimetallic Contacts," British Ministry of Supply, Pamphlet No. 70-732, December 1955, H. M. Stationery Office, London.

WHILE A LARGE amount of information has now been accumulated on the intrinsic corrosion resistance of most commercial metals and alloys, and is of substantial value in deciding the appropriate specification, all practical users are aware of the anomalies which may arise between laboratory results and actual service tests. Of the many variables which may intrude, contact corrosion between dissimilar metals in a conducting solution is one from which many engineers have suffered and which cannot always be detected with certainty.

Recognizing the need for more up-to-date and reliable information, the Corrosion and Electrodeposition Committee of the Inter-Service Metallurgical Research Council (the



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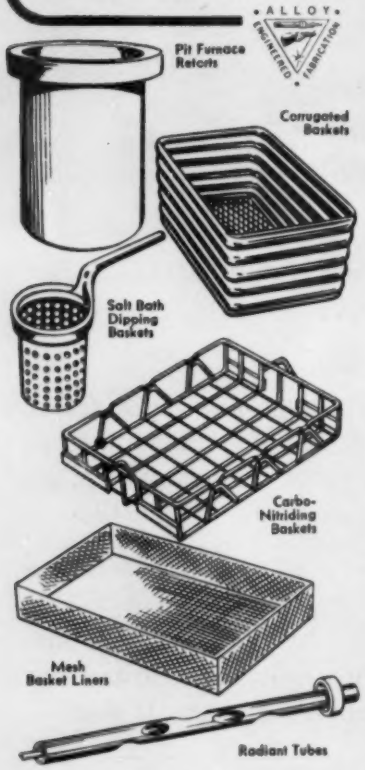

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Contact Corrosion . . .

Admiralty and Ministry of Supply) has published this pamphlet, which, while intended primarily for the Services, will be a useful supplement to the knowledge of the subject existing in industries faced with similar problems. In a foreword, Prof. A. J. Murphy, chairman of the council, points out that available published information, though extensive, has often been found inadequate and sometimes misleading, and emphasizes the difficulty of conveying concisely the essentials of the subject to the non expert.

The center of focus of the pamphlet is a table in which 16 metals are arranged against the same 16 as possible "contact metals" and the resultant combinations classified into four groups, A, B, C, and D, according to an ascending degree of acceleration of corrosion. The first ten of these materials are in a sequence approximately similar to the order of nobility indicated by laboratory tests against a saturated calomel electrode in sea water, starting with gold and the platinum metals and ending with magnesium alloys. The remaining six materials, which include stainless steels, chromium, titanium and aluminum, are not so arranged. The introduction to the table is contributed by U. R. Evans, chairman of the committee, and Mrs. V. E. Rance, and contains sections on the electrolyte and its effect, the conditions of the metal or alloy, considerations arising when a metal is employed as a protective coating, the influence of surface area and microgalvanic phenomena, and the incidental contact effect which may arise from normal fabrication or construction, in particular contamination by such materials as graphite or carbonaceous residues.

The treatment of methods of prevention of contact corrosion, which is the aspect of most importance to the practical engineer, not unnaturally repeats many items which are normal practice where high standards of construction are specified, but is a useful reminder of the dividends paid by attention to simple details, such as adequate insulation of joints. The table itself is also accompanied by abundant notes in which detailed modifications of the primary groupings are given and

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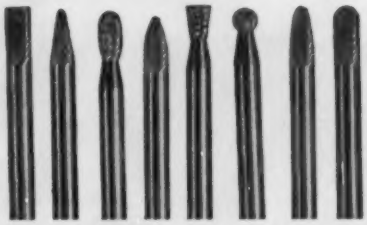

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Contact Corrosion . . .

precautions to avoid unforeseen secondary effects are described.

There are two appendices which, while primarily intended for service engineers, will appeal to other technologists as sensible and valuable additions. The first gives the full list of names, addresses and telephone numbers of the reference authorities together with those of the appropriate establishment concerned with the scientific work on the subject. In the second, all the relevant British standards, including aircraft materials and components, British Standards Institution schedules and Ministry of Supply Directorate of Technical Development specifications are tabulated against the group number of the metal or alloy in question so that the available data in the table can immediately be extracted.

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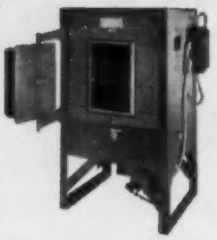

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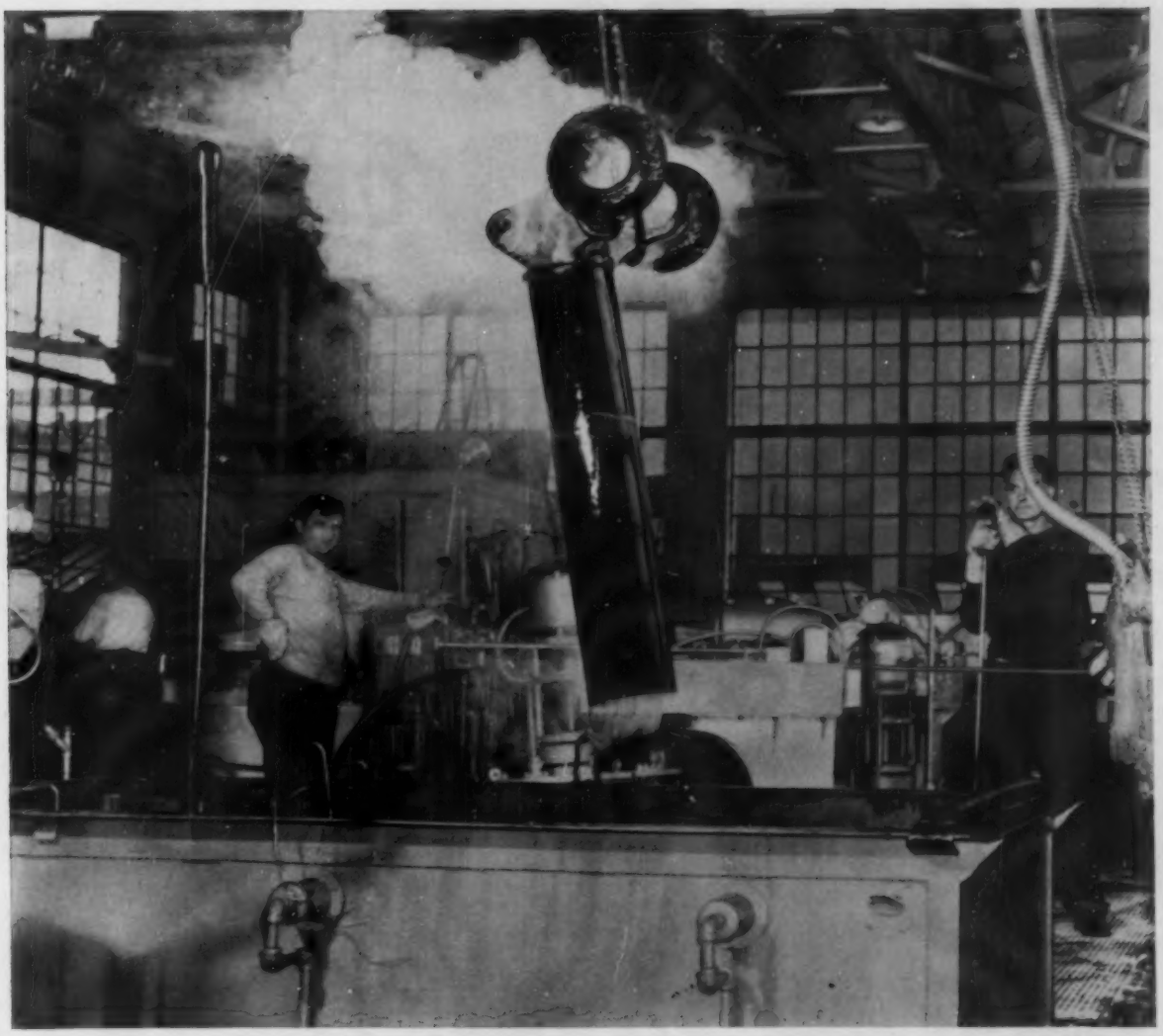
Reducing Phosphorus in Foundry Iron

Digest of "Reducing the Phosphorus Content of Foundry Iron", by R. I. Higgins, *Iron and Steel*, Vol. 29, August 1956, p. 373-378.

SINCE LOW-PHOSPHORUS ORES (containing 1% P or less) are becoming scarcer in England, methods for making low-phosphorus iron from high-phosphorus ores are now being investigated.

By a reduction roast of limonite ore containing 25% Fe and 0.43% P, followed by crushing and magnetic concentration, a product is obtained with 41.8% Fe and an iron to phosphorus ratio of 91 instead of 58. The iron made from this product contains only 1.1% P (compared with 1.7% P that the original limonite ore yields). In a Swedish ore containing calcium phosphate, a different reduction method is used. The phosphorus is reduced from 0.06% to 0.01% by washing with dilute HNO_3. Another method involves the treatment of the ore with HCl gas to give volatile $FeCl_3$, leaving phosphorus and other impurities in the residue. The volatile Fe_2O_3 is purified with steam and the HCl is recovered and re-used. Such chemical treatments however are too expensive for large-scale reduction of iron ores.

Dephosphorization in the blast furnace is practically impossible without costly modification of the process. Phosphate in the charge is reduced at about 2190° F., and the phosphorous is then absorbed in the iron. If the charge in the furnace were much hotter, some of the reduced phosphorus vapor might pass out at the top without being absorbed, but the required temperature is not known. The dephosphorizing action of blast furnace slag is negligible, the concentration of $CaPO_3$ in it being only about 0.1% at the usual hearth temperature. With temperature as low as 2280° F., and a sufficiently fluid basic slag, or with a slag high in iron oxide, phosphorus might be oxidized into the slag, but maintaining slag fluidity would be very difficult, and silicon and manganese would be removed from the iron along with phosphorus. All these modifications of blast furnace practice are considered impractical at present. *(Continued on p. 186)*



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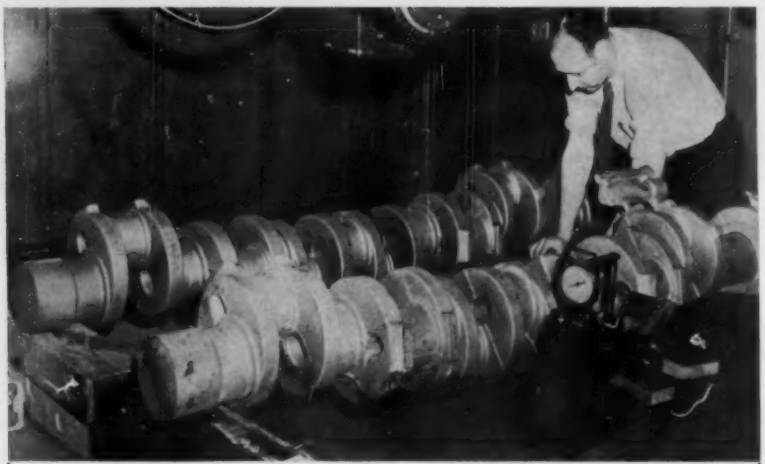

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Reducing Phosphorus . . .

Molten pig iron might be dephosphorized by reaction with slag, but silicon and manganese would be removed first from the metal. At temperatures below 2280° F., phosphorus could be oxidized from the iron without loss of carbon, and this might also be done in part at higher temperatures. Basic bessemer steel is low in both phosphorus and carbon, and can be separated from its slag and treated with coke in another vessel to restore the carbon, or the high-phosphorus pig iron can be blown with CO instead of air, in the presence of basic slag just below 2280° F., to remove phosphorus but not carbon.

The basic openhearth process can also be used to remove phosphorus before the carbon is all oxidized. By adding ore to 1.46% P pig iron in such a furnace, the phosphorus is reduced to 0.42% in 5 hr., with 1.96% C and 0.12% Mn remaining in the metal.

Dephosphorization by ladle treatment is simpler. This is done by pouring high-phosphorus iron into a ladle holding molten lime-fluorspar slag containing 35 to 75% iron ore or mill scale. In one test phosphorus was reduced from 0.295 to 0.035%, and carbon from 3.25 to 2.64% by such treatment, and in another phosphorus from 1.25 to 0.81% and carbon from 3.41 to 3.27%. But, unfortunately, silicon and manganese are always removed in greater proportions than is phosphorus.

Another method involves feeding cold powdered oxidizing slag into the stream of iron entering the ladle. The phosphorus content is reduced in bessemer steel from 0.2 to 0.075% in this way, but with carbon not over 0.2%.

By blowing oxygen on the surface of molten high-phosphorus pig iron in a converter with a basic slag for about 9 min., phosphorus is reduced from 1 or 2% to about 0.4%, with 1.8% or more carbon and some manganese remaining in the iron. The rotary mixing converter, using oxygen and a basic slag with temperature below 2280° F. oxidizes phosphorus from pig iron before loss of all the carbon. Such treatments seem more attractive than ladle treatments involving prior melting of slag, but the question of ease of control remains to be

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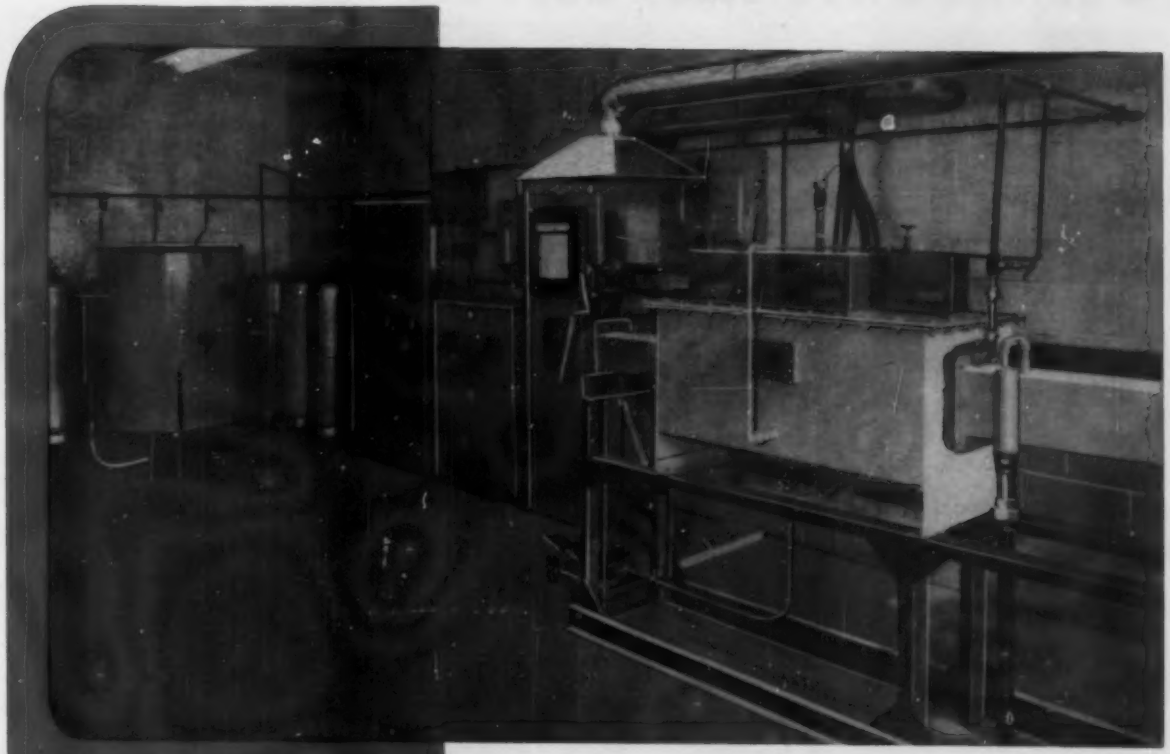

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Reducing Phosphorus . . .

established. Replacing the silicon, manganese, and part of the carbon also raises a problem.

Some dephosphorization can be accomplished in a basic cupola, but more data on this process are needed. The oxidizing slag would remove silicon and manganese as well as phosphorus but carbon might be kept high. In one test with 0.74% P iron in a basic cupola the melted product contained 0.45% P, 3.82% C, 0.14% Si and 0.37% Mn.

Since iron castings must contain at least 1.5% Si and about 0.6% Mn, these elements would have to be replaced to make dephosphorized iron useful in the foundry. This could be done by adding FeSi and FeMn to the iron in the ladle, or to a cupola charge on subsequent remelting. Or the cupola could be run with a siliceous high-manganese slag at a high temperature for carbon reduction of silicon and manganese from the slag. This could also be done on melting in a rotary mixing converter, or in an electric arc furnace. These processes have not been tried but should be effective, according to the author.

Steel scrap might be used as a low-phosphorus source of iron for foundry use where it is cheaply available, but in the acid cupola it picks up carbon only up to 2.6%, which is too low for gray iron castings. Thus steel can be used in the acid cupola only to the extent of 30% of the charge. But if a basic cupola is used, a maximum of 4% C would be absorbed from steel scrap, which would then serve well for the entire cupola charge. The basic cupola however has not yet been fully evaluated in England.

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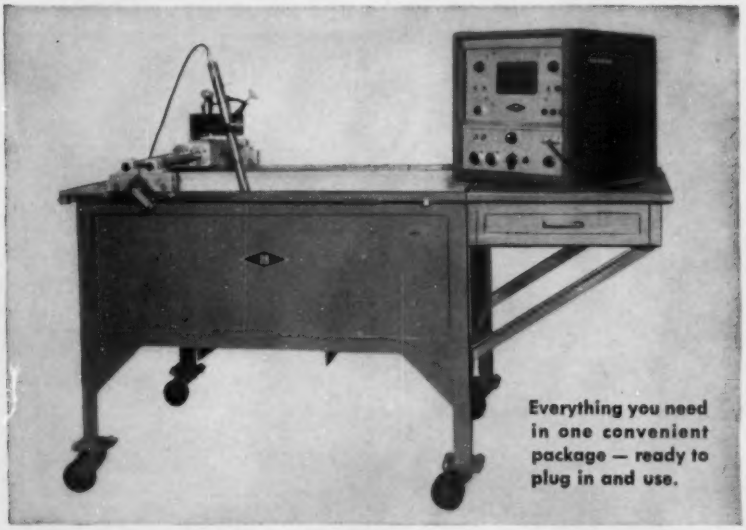

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Titanium Alloys for Sheet Rolling

Digest of "Department of Defense Titanium Sheet-Rolling Program", by W. J. Harris, Jr., Report No. 46, Titanium Metallurgical Laboratory, Battelle Memorial Institute, June 21, 1956, 12 p.

AIRFRAME CONTRACTORS long have been in unanimous agreement as to the urgent need for the commercial production of improved titanium alloys for future high-performance aircraft and missiles. Producers of these alloys have been working assiduously toward this end, but the problems of time and adequate funds have been perplexing.

The Titanium Steering Group of the Department of Defense moved into the picture almost two years ago with the idea of surveying the situation and making recommendations for accelerating alloy development. The Titanium Metallurgical Laboratory was organized at Battelle, and as a coordinating agency, has been working closely with alloy producers, users and military groups, looking particularly toward expediting the commercial production of titanium sheet with desired properties.

Sheet alloys are now being produced to a minimum yield strength of 110,000 psi. They are used in the annealed condition. At this strength level, titanium offers some advan-

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Titanium Alloys . . .

tages over certain competitive materials, but in view of high cost it appears that large-scale applications must await the introduction of higher-strength alloys with good formability and adequate stability under load at a temperature in the neighborhood of 800° F.

In the annealed condition, the highest useful specification yield-strength value at room temperature is 120,000 to 130,000 psi. While alloys of higher annealed strengths are possible, sheets of these analyses cannot be formed or worked because of limited ductility and the lack of practical experience in handling materials with this combination of strength and ductility.

Heat treatment of titanium alloys will be necessary to achieve yield strengths at room temperature of 150,000 to 175,000 psi. Many alloys made in commercial ingot quantities respond to heat treatment and show strengths in this range. However, only a few have overall promise as structural materials and none are being used in the heat treated condition at present.

After due study, the Titanium Metallurgical Laboratory concluded that a program of assistance should have these objectives:

1. To develop optimum techniques for production of new sheet alloys possessing adequate uniformity, reliability, strength, fabricability and elevated-temperature characteristics, with minimum room-temperature yield strengths of 130,000 psi. annealed and 160,000 psi. heat treated.

2. To develop design engineering data required for the use of these new alloys in military equipment.

3. To enable manufacturers of military equipment to evaluate the suitability of these alloys in sheet production quantities and to establish the necessary manufacturing data.

The first objective might be reached by contracting with titanium producers, the second by contracts with appropriate laboratories or fabricators and the third by contracting with companies in the aircraft and missile industries.

In view of the limitations on manpower, facilities and funds, it was considered necessary to concentrate attention in the sheet-rolling pro-

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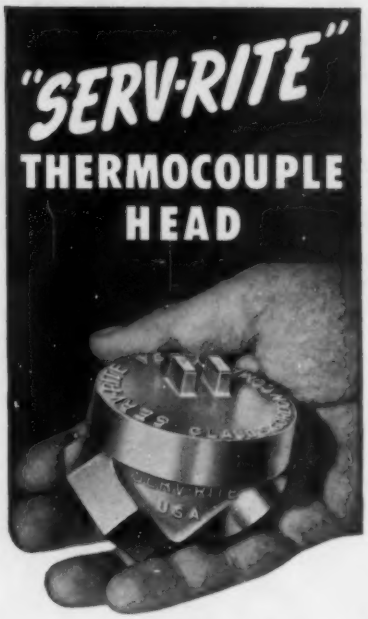

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Titanium Alloys . . .

gram on a small number of alloys, to expect a reasonable chance of bringing them into early production. Various candidate alloys were nominated by titanium producers. After weighing their stated properties against "target" properties established by a joint selection committee (headed by N. E. Promisel of the Navy Bureau of Aeronautics), four were considered to come close to the target goals and one other, not fully developed, seemed to have possibilities for scaling up to the requirements. They are as shown above, with ultimate tensile strengths in the heat treated condition.

Properties of Alloys for Sheet Rolling

Alloy	Ultimate Tensile Strength, Psi.	
	Solution Treated	Aged
4 Al, 2 V, 1 Cr, 1 Mo (a)*	100,000	180,000
2.5 Al, 15 V (a)	100,000	180,000
3 Al, 6 Mo (b)	135,000	180,000
4.5 Al, 3 Mo, 1 V (b, c)	150,000	170,000
6 Al, 4 V (a, c)	130,000	170,000

(a) Mallory-Sharon Titanium Corp.
(b) Rem-Cru Titanium, Inc.
(c) Titanium Metals Corp. of America
*Not fully developed as yet.

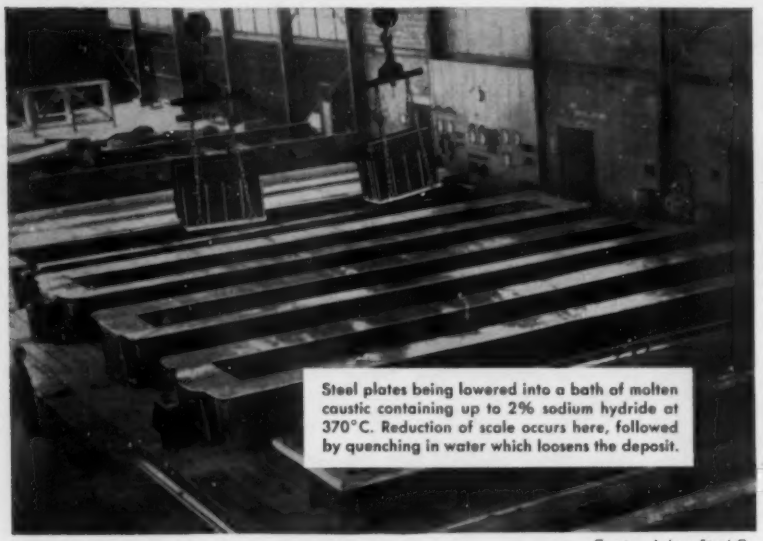
Three ground rules were laid down prior to the final selection of the alloys for the sheet-rolling program. First, only those alloys would be chosen which already had been produced at least once in ingot size of the order of magnitude used in commercial production of sheet. Second, only those alloys would be picked for which there were sufficient data to indicate the probability of success in meeting the target sheet properties. Finally, the desirability of selecting alloys which would be available to all producers was emphasized.

Contracts have been negotiated with producers for development of optimum techniques for production of these new titanium sheet alloys. Each contract covers the variables under study and an attempt will be made to establish the effects of the following on the properties, uniformity and quality of the sheet: sponge hardness or composition, ingot characteristics, mill processing procedures, surface treatment processes, and heat treating cycles.

Enough material will be melted and processed under these contracts to demonstrate that the alloy will have satisfactory characteristics, including the promise of adequate uniformity when released for commercial production. The material will be produced in 36 x 96-in. sheets in at least three thicknesses for each alloy, ranging from 0.020 to 0.96 in.

Alloys under the sheet-rolling program that have been demonstrated to be uniform and to approach closely the target properties will be fully appraised and tested by the airframe industry and its subcontractors, following which appropriate procedures suited to the various alloys will be developed for the manufacture of parts. Incidentally, substantially more design data must be compiled on titanium alloys as applied to airframe members before they can come into wide acceptance.

Arthur H. Allen



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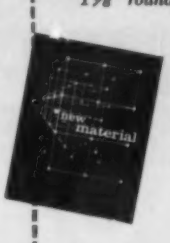

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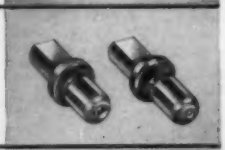

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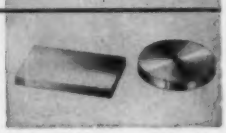

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Effect of Vibratory Stress on Life of Turbine Blades

Digest of "Strengths and Failure Characteristics of AMS 5534A (S-816) Alloy in Direct Tensile Fatigue at Elevated Temperatures", by Charles A. Hoffman, A.S.T.M. Preprint No. 68, 1956, 18 p.

UNDER steady-state operating conditions, the stresses on a turbine blade are a combination of centrifugal stress and superimposed vibratory stress. The lives of turbine blades can be considerably less than predicted by stress-rupture data alone because of the presence of the vibratory stress. In the analysis of service failures, the appearance of the fractured surface is usually used to indicate the cause of fracture. Vibratory stress is expected to cause a fracture appearance characteristic of fatigue, thereby suggesting that fatigue has reduced the blade life. However, the appearance of a blade failure is not necessarily conclusive evidence of the effect of vibratory stress. Briefly, it appears from previous studies that failure appearance and time to failure under vibratory stress are probably functions of the material used, and of stress and temperature.

The present studies were conducted on a widely used wrought blade alloy AMS 5534 A (S-816) in tensile fatigue (vibratory tensile stress superimposed on a mean tensile stress). Observations were made of the failures in relation to mean stress, temperature, vibratory stress and time to failure. In addition, metallographic studies were made to provide some insight into the relation of fracture path to crystallographic features of the alloy at elevated temperature. The effects of cyclic vibratory stress upon reduction in area and hardness at failure were also investigated.

Prior to testing, the material was solution treated for 1 hr. at 2150° F. and water quenched, then aged for 16 hr. at 1400° F. and air-cooled; the hardness after heat treatment was Rockwell C-25 to 26. Commercially available direct-tension fatigue machines were used in making the tests; the maximum and minimum stresses were maintained

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Turbine Blades . . .

at the desired level by means of electrically actuated controls which acted upon a hydraulic piston.

Three test temperatures, 1200, 1500 and 1600° F., were used. Stress-rupture data were first obtained and from these data mean stresses were selected to yield failure times at each temperature of approximately 10, 100 and 1000 hr. with zero cyclic stress. Cyclic tensile stresses up to a maximum of approximately 98% of the mean stresses were superimposed upon these mean stresses, usually in increments of ± 2500 psi. The cyclic stresses were applied at 2000 cycles per min. and the criterion of specimen failure was complete fracture.

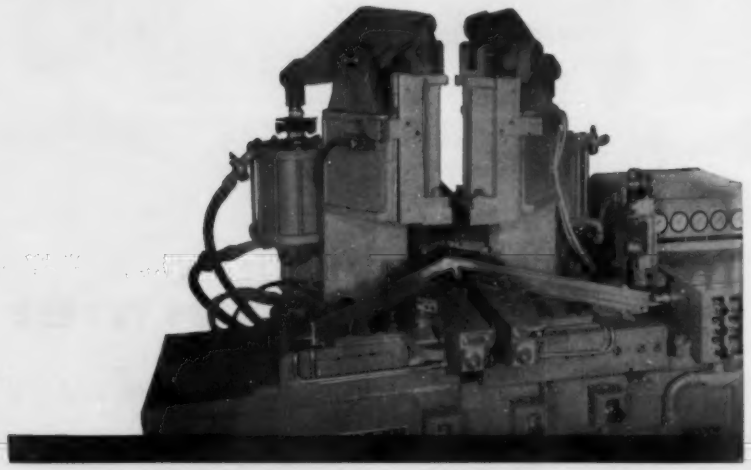
For all temperatures studied, stress-rupture plus fatigue failure generally was accompanied by reduction in time to failure because of superimposed cyclic stresses. Consequently, if service blades of this alloy with the same heat treatment have a lower life than expected on the basis of stress-rupture data, and simultaneously exhibit fatigue-type failures, vibratory stress would probably be a factor in the shorter life. Furthermore, study of the data also indicates that at all temperatures investigated, stress-rupture-type failures accompanied shorter life under some conditions of stress; therefore, blades of this alloy could have shorter life because of vibratory stress and yet appear to have failed by stress-rupture.

During the course of this investigation the calculated time to stress-rupture failure under cyclic stress conditions was compared with observed times. The assumptions were made that the amounts of stress-rupture damage at the various stress levels during a stress cycle were directly proportional to the times at these stresses and were additive. A similar assumption of cumulative damage was applied by Miner to the case of fatigue at room temperature. Although the present assumption of cumulative stress-rupture damage may be a considerable simplification, it provides an interesting first approach to this problem. An equation relating time to fracture by stress-rupture to mean stress and stress ratio is derived in the appendix of this paper. Hypothetical curves obtained from this derived expression do predict an observed decrease in life with increased stress ratio; however, the quantitative agreement with the data is not good. At the low temperature of 1200° F. vibratory stress is more damaging, and at 1500 and 1600° F., less damaging than predicted by the cumulative damage theory and based upon stress-rupture data alone. The author's conclusions are:

1. Increasing cyclic stress reduced time to failure at all conditions of mean stress and temperature investigated. Under some conditions, however, the reductions, if any, were slight at the lower cyclic stresses.

2. Superimposed cyclic stresses of a given magnitude (low to intermediate) generally resulted in relatively greater reductions in life at the lower mean stresses than at the higher mean stresses.

3. Cyclic stresses of given magnitudes caused greater reduction in



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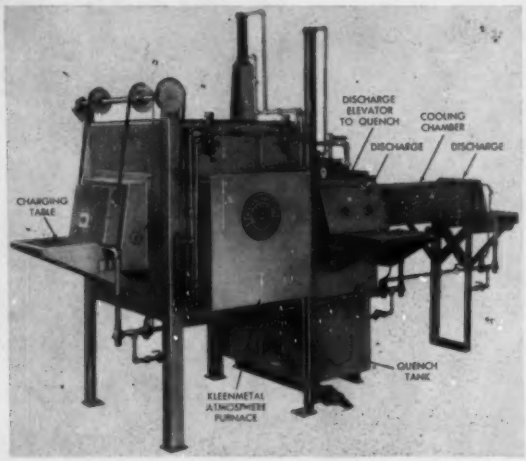

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Turbine Blades . . .

life at 1200° F. than at 1500 and 1600° F.

4. With increased cyclic vibratory stress about a mean stress, the appearance of the failure was indicated as undergoing a transition from that of stress-rupture to a combination of stress-rupture and fatigue. Further increases in vibratory stress level resulted in the appearance of fatigue failure.

5. The appearance of fatigue-type failures was generally accompanied by reductions in life because of cyclic vibratory stress.

6. Under some conditions, stress-rupture type failures occurred even though the specimen life had been lowered by cyclic stress.

7. Stress-rupture fracture occurred by transgranular cleavage and shear at 1200° F. and occurred by intergranular and transgranular shear at 1500 and 1600° F. Fatigue fracture was transgranular at all temperatures and did not appear to follow crystallographic planes.

8. The percentage reduction in area at failure (fracture ductility) decreased with increased vibratory stress at all conditions investigated.

G. M. SINCLAIR

Grain-Boundary Fracture Surfaces

Digest of "Some Observations on the Structure of Grain Boundary Fracture Surfaces", by H. C. Chang and N. J. Grant, *Transactions*, A.I.M.E., Vol. 8, Section 2, October 1956, p. 1241-1257.

SPECIMENS of a high-purity 20% Zn-Al alloy, with a grain diameter of 1 to 3 mm., were subjected to creep at 500° F. (with rupture times from ½ to 3 hr.), and to room-temperature tensile tests. The fractures were essentially intercrystalline, and the fracture surfaces were examined both by optical microscope and X-ray back-reflection methods.

The fracture surfaces were observed to be neither smooth nor flat, but composed of fracture facets, the structure depending upon the orientation of the grain boundary with respect to the tension axis, and the proximity of other grain boundaries. For creep specimens, fracture sur-

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Grain Boundaries . . .

faces of nearly horizontal boundaries contained small cells, or facets, at a series of levels and apparently following a definite geometry. Dark valleys between the cells had rather flat troughs, and both troughs and plateaus had similar deformation markings. The Laue photograms indicated a layer of recrystallized material of varying thickness and grain size at the fracture surface, with varying degrees of grain distortion beneath.

In the case of intercrystalline fractures of non-horizontal boundaries, the cells generally were much finer and the differences in level were less, particularly for grain boundaries parallel to the specimen axis. In addition, the surfaces appeared very bright, due presumably to considerable rubbing between the sliding surfaces after partial fracture. Surfaces with less rubbing action were duller, coarser and showed a thicker recrystallized layer.

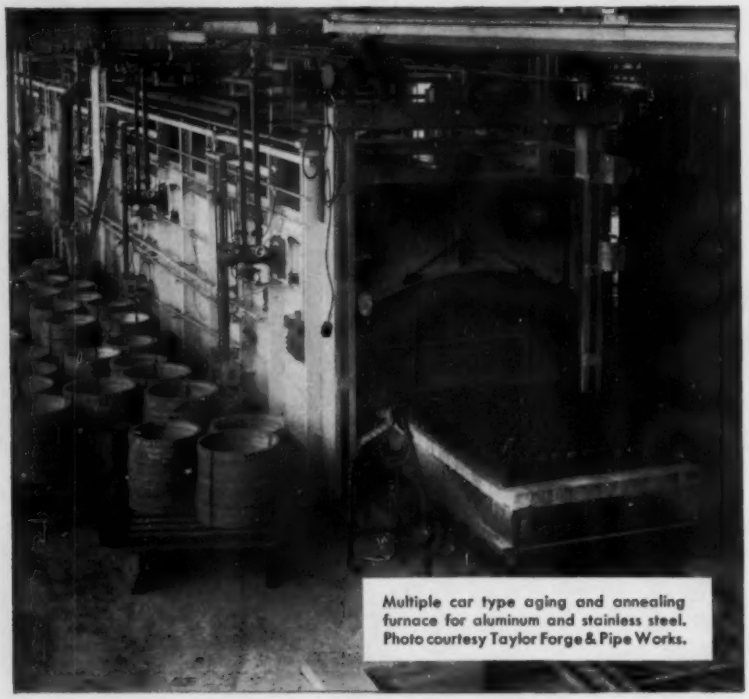
Room-temperature tensile tests were made to check the effect of a lower temperature and a higher strain rate. Cracking was essentially intercrystalline, except in a triple point region, and was initiated at those parts of the boundary which were intersected by heavy slip bands. It is suggested that cracks were formed as a result of stress concentration or a pile-up of dislocations at such intersections.

The evidence indicated that the heavy slip bands were probably an integral part of the cracks in at least one case. Deformation markings (folds) but no heavy slip bands were visible on the other side of the boundary. In general, the deformation in the grain was uniform, the heavy bands occurring close to the fracture zone. Grain-boundary sliding was very limited, and the fracture surfaces showed a cold worked layer.

Previous work has shown that intercrystalline cracks may be initiated either by restriction of grain-boundary sliding, or by a bending stress created when contiguous grains deform by different amounts. Such cracks propagate along boundaries across which the highest normal stress is exerted. To account for the fact that the fracture surfaces are not smooth, it is postulated that the cracking mechanism is as follows: localized fracture along the boundary; shearing along slip planes, which results in new cracks parallel to the boundary; and finally, separation of the inclined surfaces arising from crack enlargement. Such a process would produce the plateaus and valleys observed. The extent of the subsequent rubbing or smearing action would depend upon the height of the plateaus and the angle between the boundary and the tensile stress.

The estimated thickness of the heavily deformed layer (of the order of 40×10^{-4} cm.) was in general agreement with values obtained by Perryman (*Journal*, Institute of Metals, 1954-1955, Vol. 83, p. 369) by a continuous electropolishing method. The greater ductility of the author's material would account for some differences noted with horizontal and inclined boundaries.

R. C. A. THURSTON


Multiple car type aging and annealing furnace for aluminum and stainless steel. Photo courtesy Taylor Forge & Pipe Works.

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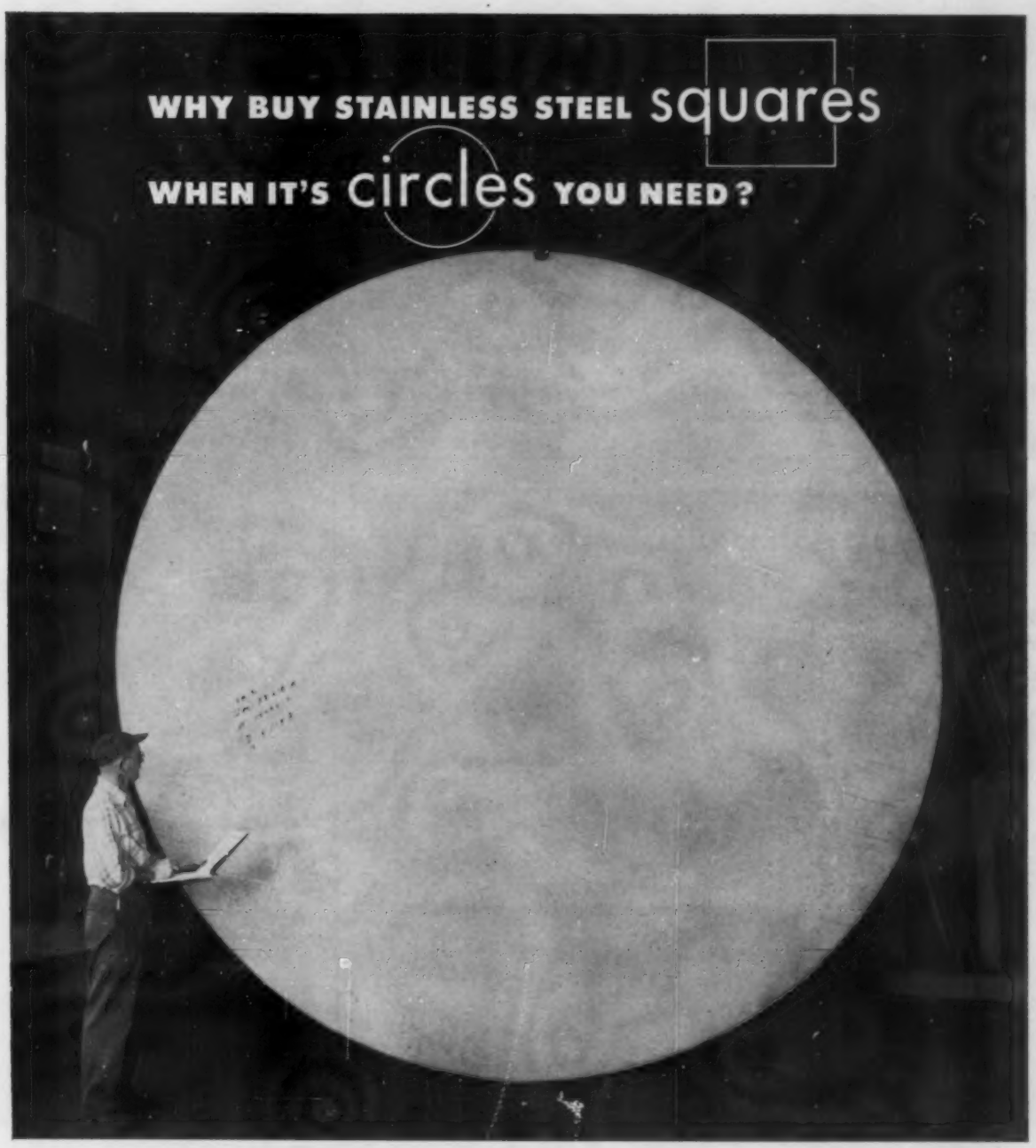

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New Vitreous Enameling Process

Digest of "Surface Protection by Coating", *Engineer*, Vol. 202, Dec. 7 1956, p. 822-823.

VITREOUS ENAMEL coatings are usually applied by spraying the cold, previously fused enamel powder on the metal and subsequently melting it in a furnace. Such coating materials must have lower melting points than the metal coated, and they cannot be used on articles that cannot be heated in a furnace.

A new process for applying protective coatings of high melting point, developed by the Norton Co. and called the "Rokide" process, is not subject to these limitations.

In this process a rod of the coating material is fed through the nozzle of a spray gun in which an oxy-acetylene flame is surrounded by a tubular jet of compressed air. The end of the rod is melted in the flame, and fused particles are blown against the article to be coated. The article does not get very hot; even magnesium, carbon, glass, and plastics can be coated in this way. Adhesion is better if smooth articles are first roughened by shotblasting, or by a sprayed metal coating. Coatings as thick as 0.1 in. have been made. For coatings 0.01 in. thick the application rate is about 70 to 150 sq. in. per hr., depending on the material. The only limitation is that deep holes less than 3 in. diameter cannot be coated inside.

The process was first developed as a means of applying a refractory edge to such articles as steel rocket-motor nozzles, which may erode very fast at the throat in service. The standard materials applied are "Rokite A" (alumina), "Rokite Z" (zirconia), and "Rokite ZS" (zircon). Their melting points are about 3600, 4500 and 3000° F., respectively. Zirconia is about 50% heavier than the others and twice as costly, and all have 8 to 12% porosity. The thermal expansion and conductivity are much lower than those of metals, zirconia having the highest expansion and lowest conductivity.

The coatings are inherently uniform in quality because only well-fused particles can adhere to the deposit. The interlocking layer structure gives some mechanical flexibility and excellent resistance to thermal shock. Even sudden fusion of a spot on the surface produces only local cooling cracks that are fine and shallow. The porosity of the coatings prevents complete protection against corrosive agents, which in time may help to bring about spalling from thermal stresses, especially on convex surfaces.

Rokide coatings are also useful for electrical insulation and resistance to combustion atmospheres and mechanical wear. Zirconia gives the greatest thermal protection, and alumina the best wear resistance. A coating of the latter on top of the former has therefore been successful in some applications requiring this combination. In corrosive service zircon may be preferred, and also has high resistance to wear.

Voltage breakdown tests showed 500 v. for a coating 0.002 in. thick, up to 1500 v. for 0.01 in. thick, with higher values if the porosity is sealed by silicone resin varnish.

The coatings have a rough surface, corresponding to 100 to 200 μ in. They can be ground and lapped or polished smooth. Diamond or silicon carbide wheels, used dry with a very light feed, are preferred for grinding.

G. F. COMSTOCK

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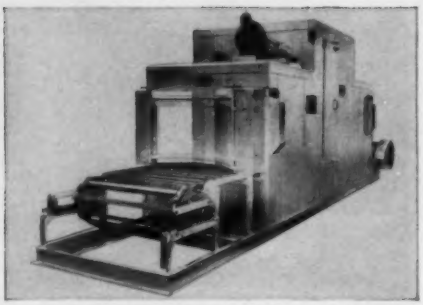

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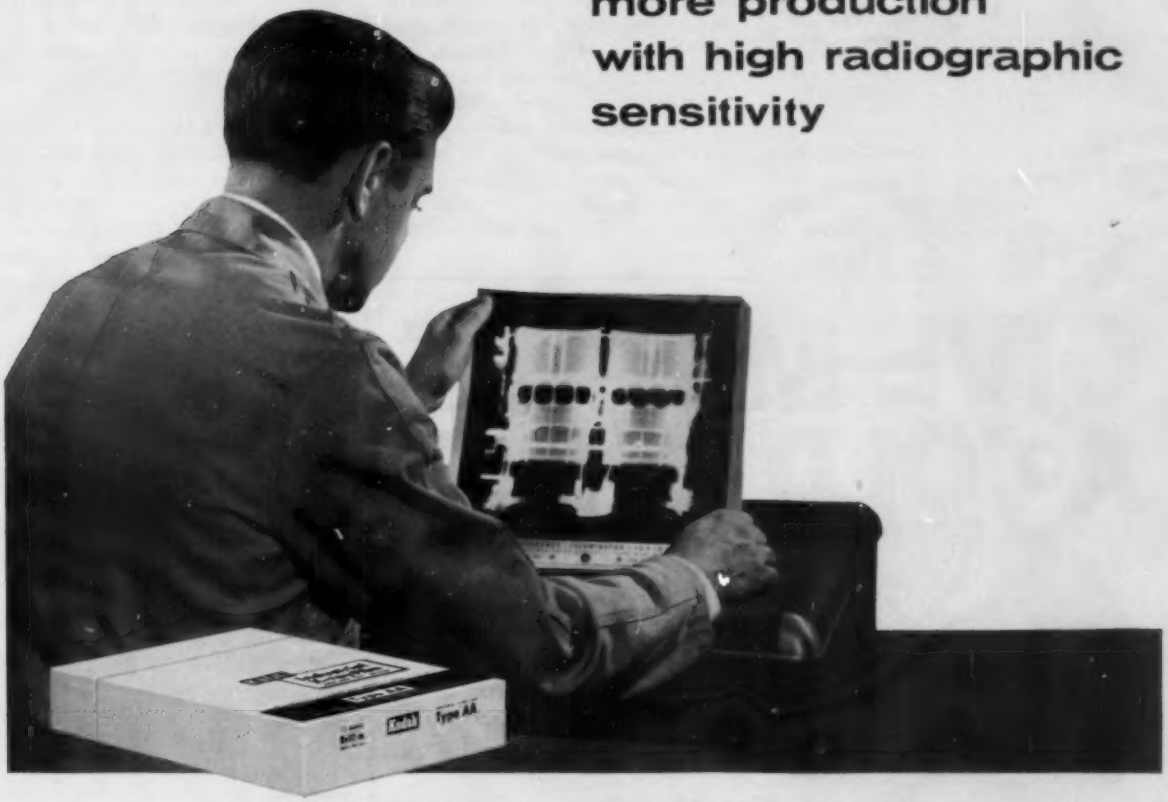

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Testing Fuel Elements for Nuclear Power

Digest of "Metallurgical Research and Development of Nuclear Power", by H. K. Hardy, *Journal* of the Institute of Metals, Vol. 84, March 1956, p. 229-238.

THE CONTINUED DEMAND for electricity in Great Britain is expected to increase, with the prospect that coal-fired plants will be unable to meet the demand in the foreseeable future. Nuclear energy offers the only other possible major power source. The design and development of nuclear power reactors is dependent upon the metallurgical development of fuel elements.

The British program emphasizes heterogeneous reactors in which the fuel element is essentially the fissionable material contained in a can. The can serves to locate the fuel in the reactor and to keep the fuel proper out of contact with the coolant, since the fissile materials (uranium) are usually quite reactive chemically.

The canning or cladding material must not react with the coolant in any manner nor with the fuel (or at least any potential interaction between the fuel and cladding must be suppressed by suitable treatments or the use of nonreactive interlays). The mechanical properties of the cladding must be such as to adjust, under irradiation, to conform to shape changes in the fuel and yet provide necessary support for the fuel. The fuel element as a whole must be dimensionally stable at operating temperature, under fluctuating temperature, and under irradiation at the operating power rating. With each fission two new atoms are produced which occupy more than twice as much volume as the fissioned atom of uranium from which they came. All these factors pose a considerable problem in containment of the fuel.

If a time table is imposed on the effort to achieve a successful reactor design, it is necessary to compromise between the problems and the ability to provide satisfactory solutions within a specified time limit. If a hypothetical reactor is to be designed on the basis that five years will be allowed between initiation of design and power production, it is reasonable to allow the fifth year to cover fuel element charging, commissioning and operating tests, and working up to full power rating. Thus the fuel elements must be completed in a four-year period, implying that the design must be basically complete one year earlier. Assuming that the first year will be consumed in feasibility studies and general design arrangements, this leaves the second, third and fourth years available for design, ordering, installation, commissioning, and production of the first fuel charge to load into the reactor. The time table requires that flow sheets for the fuel and cladding operations be complete in all except some details by the end of the second year – that is, three years before full-scale power production. The research and development work on the alloys for fuel and cladding must also be complete at the same time. This requires starting with a range of materials and narrowing the choice until final selection can be

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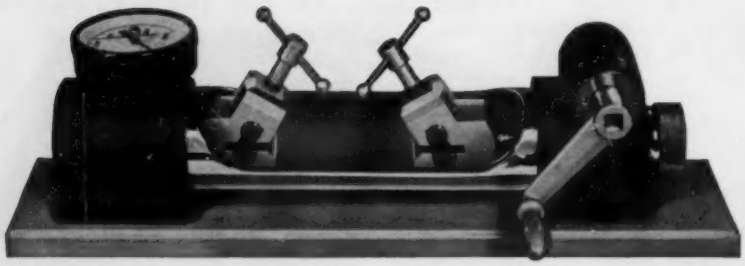

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Fuel Elements . . .

based on accumulated available information. Concentration on a few materials allows investigation of production methods and a progressively increased scale of development work. This will require as thorough testing of the fuel and cladding as possible for compatibility, temperature stability under both steady state and thermal cycling, resistance to irradiation, mode of deformation at service temperature, grain size, response to heat treatment, effect of impurities, possible surface treatments and other modifying factors.

Prototype development will require work on a semiproduction scale which should be completed about 18 months ahead of operation on a production scale. Prototype production elements will also require extensive testing so that as little is left to chance as possible.

Metallurgical research on a laboratory scale should be basically exploratory and of a continuing nature, covering such areas as compatibility tests, oxidation and corrosion tests, behavior of uranium and its alloys, creep testing, powder metallurgy, and various routine examinations.

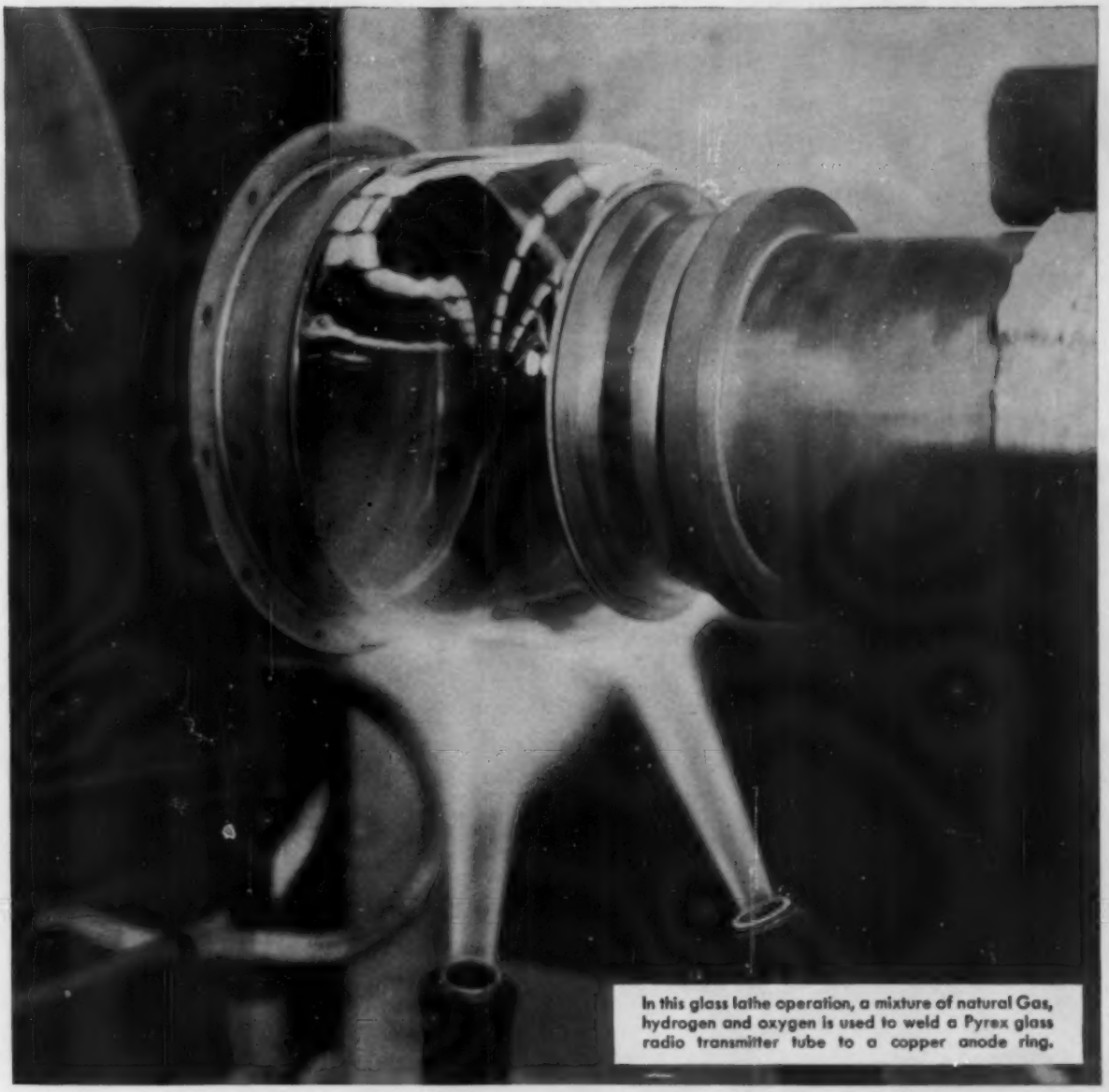
Development scale research should include the working out of processes, fabrication and testing methods, and production of prototype fuel elements for test purposes.

C. O. Smith

Heat Treatment Cures Stress-Corrosion Cracking

Digest of "A Case History of Stress Corrosion Cracking of Austenitic Stainless Steel," by I. D. G. Berwick, *Corrosion*, Vol. 12, December 1956, p. 58-60.

Stress-corrosion cracking of stainless steel components is rare, although austenitic types are susceptible to this type of failure in certain environments. An example is stress-corrosion cracking of stainless steel strainer plates used in pulp mill digesters. They are installed on the inner circumference of the digesters to form an annular ring through which the cooking liquor is withdrawn. A circulating pump returns the liquor to the digester at



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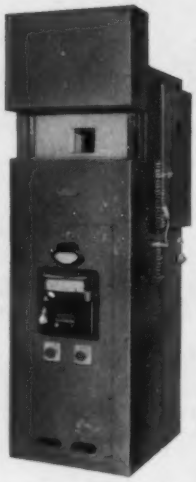

Model 30 (pictured) Automatic temperature control. From 600° F. to 2000° F., use for ashing, drawing, igniting, tempering, etc. Above 2000° F., for sintering, melting, clinkering, fusing and high speed hardening. For use with 230 volts, 50-60 cycles, single phase power supply; automatic controller for 115 volts, 50-60 cycles, single phase.

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Stress-Corrosion . . .

a remote point to distribute heat uniformly. The plates serve to prevent wood chips from circulating with the liquor.

The fluid medium is a calcium-base sulphite liquor containing 1.1% combined sulphur dioxide and 7.5% total sulphur dioxide, together with wood resins and traces of chlorides. It is circulated at a temperature of around 295° F. and averages 3.0 in pH value.

In the complete annular ring there are 43 separate plates, each comprising a cast frame of Type 317 stainless steel and a Type 316 facing plate tack welded to the frame. The facing plate is bent along two lines to give it a U-shaped section, and is perforated with a large number of drainage holes.

After service of as little as six weeks, the plates became pitted and coated with an adherent calcium sulphate-wood resin scale. In addition, the facing plates suffered severe bursting failures at the bends, the metal appearing to have lost all strength at these points. No signs of corrosion or fracturing were noted on the frames. Attempts were made to repair the pits and fractures by patch welding, but this resulted only in further failures in even shorter intervals.

The path of failure was found to be almost always transgranular, which, on the basis of other investigations of the phenomenon, suggested that the bursting failure and loss of strength of the strainer plates was due primarily to stress-corrosion of the steel. The cooking liquor unquestionably provided an environment conducive to stress-corrosion, since in acidic solutions small amounts of chlorides can produce such corrosion in stainless steels, and solutions containing hydrogen sulphide and other sulphur-containing substances are also dangerous, particularly when associated with reducing conditions. Stress required to produce stress-corrosion cracking may be extremely low. Cold working, quenching, grinding, welding or restrained thermal expansion all can introduce internal stresses far in excess of the value required to make stainless steel subject to such cracking.

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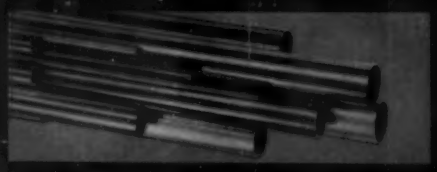

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Stress-Corrosion . . .

ing stress-corrosion is some form of stress-relieving treatment to remove or reduce residual internal stresses, plus attention to the design of the component to avoid unduly high external stresses. Since the benefits of stress-relief are lost if the part is subsequently cold worked or subjected to thermal stresses, it is recommended that the strainer plates of the digester be punched, bent and tack welded to the frames, followed by heat treating of the complete units at 1550 to 1600° F. for 30 min., followed by air or furnace cooling.

Because intergranular chromium carbide precipitation occurs in the temperature range of 900 to 1560° F., some degree of sensitization is to be expected during the heat treatment. To avoid this, it is recommended that a low-carbon alloy be specified. To minimize pitting attack, a Type 317 stainless steel alloy is preferred for the face plates. With its higher molybdenum content, this alloy effectively withstands exposure to the cooking liquor.

A further change is to tack weld the plates to the frames in three separate sections, thus eliminating the bending operation. With these modifications, no stress-corrosion cracking of the strainer plates has been observed after a year of operation, and pitting corrosion has ceased to be a serious problem.

ARTHUR H. ALLEN

Corrosion Behavior of 18-8 Stainless in Boiling Acid

Digest of "Behavior of 18-8 Stainless Steel in 2 Normal Boiling Nitric and Sulphuric Acid Mixtures," by C. E. Krystow and M. Balicki, *Corrosion*, Vol. 12, September 1956, p. 39-44.

AUSTENITIC stainless steels are known to corrode rapidly in dilute sulphuric acid, but hardly at all in nitric acid. Their corrosion in all mixtures of the two acids, however, is not well established, and this has now been investigated on Type 304 steel containing 0.043% C, 0.56% Mn, 0.50% Si, 9.96% Ni, and 18.26% Cr in a series of 2 *Normal* acid mixtures, from 2 *N* HNO_3: 0 H_2SO_4 to 0 HNO_3:2 *N* H_2SO_4. The test specimens were 2-in. diameter disks of annealed 0.186-in. thick plate, finished with 320-grit abrasive paper. The surface areas of the 28 specimens ranged from 6.61 to 6.68 sq.in. except for one value of 6.44 sq.in.

The strengths of the 2 *N* acids were checked by titration, and 18 2 *N* solutions were carefully prepared by mixing; their acid contents ranged from 11.8% HNO_3 and no H_2SO_4 to no HNO_3 and 9.2% H_2SO_4 by weight. Although the acidity diminished from the nitric to the sulphuric end of the series, the unknown extent of dissociation of each acid made it impossible to state definitely the acidity of each mixture. Likewise the oxidizing power decreased as the H_2SO_4 in the mixture rose, but possible complexing prevented a statement of definite values. The boiling points varied from 218° F. for 2 *N* HNO_3 to 216° F. for 2 *N* H_2SO_4.

Each specimen was immersed 24 hr. in 500 ml. of one of the solutions boiling in a flask equipped with a reflux condenser. The loss in weight of each specimen was measured, and each solution of Cr, Ni and Fe was measured separately. The latter values were determined by evaporating a measured amount of the solution after a test, and analyzing the residue spectrographically. No insoluble corrosion products were present.

True corrosion rates were not determined accurately for the badly attacked specimens because pitting enlarged their original surfaces by amounts that could not be measured. The degree of pitting was estimated for many of the specimens, however, by counting the pits on three small areas at 100 ×.

In solutions between 2 *N* HNO_3 and 1 *N* HNO_3 + 1 *N* H_2SO_4 the corrosion loss was less than 20 mg. per sq.dm. per day, but in mixtures increasing in sulphuric from 1 *N* HNO_3 + 1 *N* H_2SO_4 to 2 *N* H_2SO_4 the loss increased rapidly to nearly 10,000 mg. per sq. dm. per day. The

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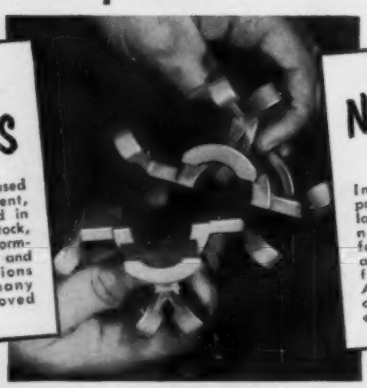
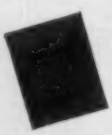


NOW 2 PARTS

Investment Casting produced the same collar in 2 parts. It eliminated all blanking, forming, pre-machining and welding. It simplified final assembly. And it *materially* reduced the cost of production."

*Details on request



Send today for our new 12-page booklet, "Modern Precision Investment Casting." It tells you the "how and why" of Investment Casting.

If you have a precision parts problem, perhaps Investment Casting can help you. If the part measures 6" x 5" or smaller, if it weighs 3 lbs. or less, if it requires starting tolerances as close as plus or minus .005" per linear inch, if it now needs 5 or more fabrication steps, *maybe you NEED Investment Casting.*

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Precision Casting Equipment and Supplies

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Photo and data courtesy of The International Nickel Co., Inc.

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Type 302, Sheet Base Price 50.00 cents per lb.
Type 430, Sheet Base Price - 39.25 cents per lb.
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in Stainless SHEET Costs!

Now you can SAVE $215 per ton in base price alone!

Many designers and fabricators who are currently using Type 302 stainless can, in numerous applications, specify Type 430 straight chromium stainless and take advantage of the 10¾ cents per pound difference in base price. Some of our customers are already saving more than $215 per ton using our 430 MicroRold stainless sheet.

The steel industry estimates that 50% of all stainless sheet applications could satisfactorily employ Type 430, the least expensive of all stainless grades, as an economical and practical material. When properly applied, Type 430 has all the desirable qualities of beauty, corrosion resistance, strength, long life and low maintenance that no other material, except stainless, can offer.

We are currently producing our MicroRold Type 430 sheets up to 48" wide in thicknesses .005" to .109" with 2B or 2D finishes; and in thicknesses .010" to .109" in No. 3, 4 and 7 finishes.

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Washington Steel *Corporation*

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Acid Corrosion . . .

data were therefore plotted with a logarithmic (or in one instance log-log) scale for the weight loss.

Charts show corrosion behavior in four zones of different characteristics. In the "passive" zone at the HNO_3 end of the series, to about 1.5 *N* HNO_3, corrosion was almost negligible; the ratio of chromium to nickel dissolved was less or not much greater than in the steel (where it was 1.83), and pits were small, shallow and far apart. In the second or "transition" zone, between 1.5 *N* and 1 *N* HNO_3, the corrosion rates increased, as the proportion of H_2SO_4 in the acid mixture rose, to a maximum at about 1.2 *N* and decreased again, and the ratio of chromium to nickel dissolved rose to above 4. The number of pits was greater than in the first zone, but remained nearly constant, showing no maximum. The pits became larger and deeper, however.

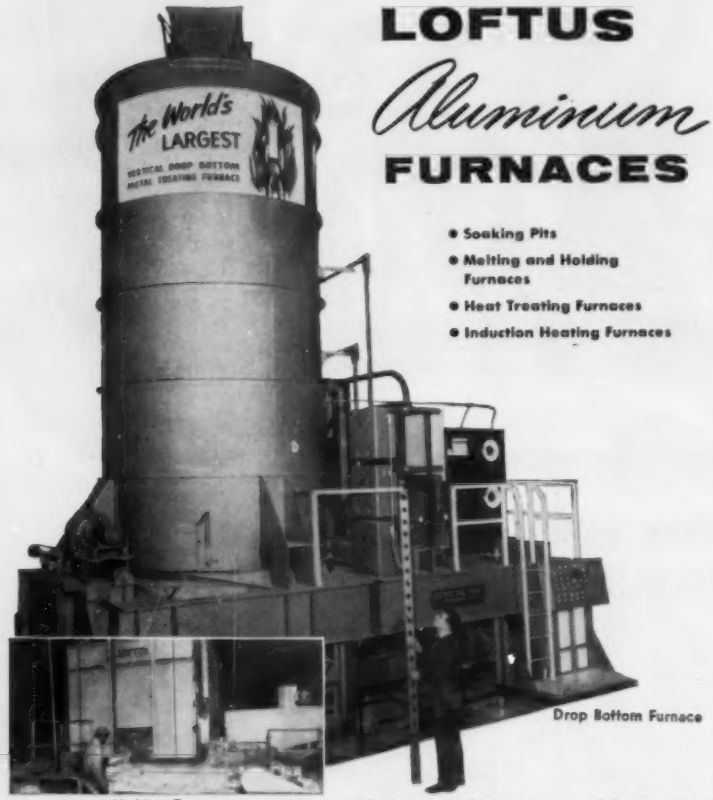
In the third zone from 1 *N* to 0.73 *N* HNO_3, the corrosion rate increased very rapidly with H_2SO_4, and the ratio of chromium to nickel dissolved fell back to 2 or lower. The pits remained about the same as at the end of zone 2. In the fourth zone, at the H_2SO_4 end of the series, the corrosion rate rose exponentially, though less rapidly in zone 3, and was several hundred times higher than in the first zone. The ratio of chromium to nickel dissolved was down to less than 0.7, indicating that more nickel than chromium was going into solution. The pits ran together and became very deep.

Owing to slight dendritic segregation in the steel the oxidized surfaces exposed to acid were not perfectly uniform and the acid attack occurred first at certain key spots that were more active chemically than the rest of the surface. Pits therefore formed at such locations. With HNO_3 these pits were few and far apart. Even chromium atoms were not completely immune to attack by HNO_3 in these tests, although about 99% of the atoms dissolved were iron.

When H_2SO_4 was mixed with the HNO_3, the oxygenated surface film was reduced at more spots, exposing more bare metal, and increasing the rate of attack. As the proportion of H_2SO_4 increased sufficiently, the oxygenated film eventually disappeared, the pits ran together, and corrosion became very rapid. The marked change in corrosion rate increase occurred when the proportion of H_2SO_4 in the mixed acids exceeded the 1 *N* HNO_3:1 *N* H_2SO_4 ratio, or between the second and third zones of the series.

The reason for the decrease of corrosion rate as the H_2SO_4 proportion increased in part of the second or transition zone of the mixed-acid series could not be explained. This hump in the corrosion rate curve is believed to be related to an increase in the solution of chromium and nickel from the steel, with a nearly constant rate of solution of iron, in these same particular 2 *N* acid mixtures of this HNO_3:H_2SO_4 series. The spectrographic technique with which this information was obtained should be used more in investigations of corrosion.

GEORGE F. COMSTOCK



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As designers and constructors of the most modern, efficient furnaces for the aluminum industry, Loftus recently completed the world's largest Vertical Travel Type Drop Bottom Metal Treating Furnace. Commenting on this ultra-modern installation, our customer says: "Loftus can be proud of pioneering this type of furnace for the metal treating industry." Whatever your furnace requirements, you can depend on Loftus for the best possible heating at the lowest possible cost.

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Here are a few of the many discriminating buyers whose reorders prove complete satisfaction with these two UNITRON instruments.

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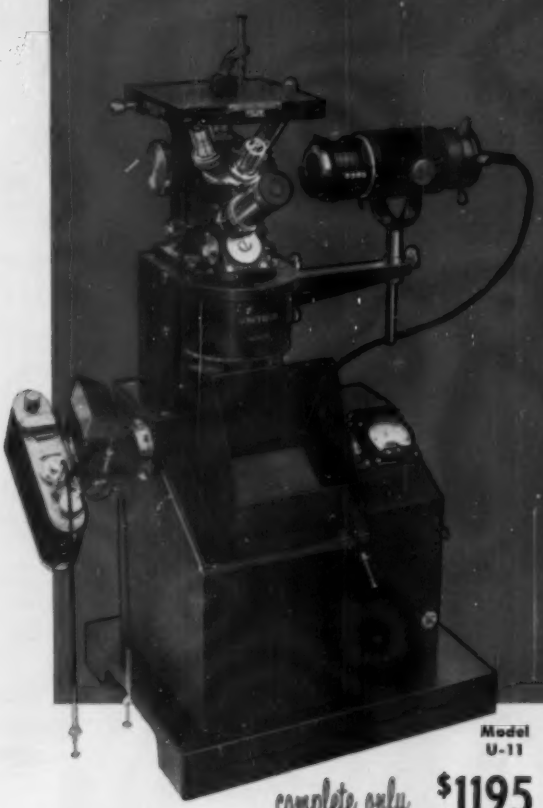

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BINOCULAR MODEL only $1379

UNITRON METALLOGRAPH and Universal Camera Microscope, Model U-11: A completely self-contained instrument of modern design for visual observation, photography, projection and measurement of both opaque and transparent specimens, using bright-field, dark-field or polarized illumination. While compact in size, it duplicates the performance of large, cumbersome instruments. Even laboratories on a limited budget can enjoy the accuracy, speed and efficiency possible only with a complete installation of this type.

- Standard optics include 5 parfocal objective lenses with revolving nosepiece, 4 photographic eyepieces on a revolving turret, 3 visual eyepieces, all coated. Magnification range: 25-2000X.
- High-intensity illuminator with variable transformer built into the microscope base.
- Built-in 3¼" x 4¼" camera. The image is automatically in focus in the camera and transition from observation to photography is instantaneous.
- Calibrated square mechanical stage with calibrated rotatable stage plate.
- Calibrated polarizing apparatus, transmitted-light accessories for transparent specimens, filters, micrometer eyepieces, film holders, cabinets, dustcovers, etc. all included.
- Additional accessories, available at extra cost include: Polaroid Land Camera attachment for "60-second" photography; 35mm camera attachment; low power (5-40X) objectives; vacuum heating stage for temperatures to 1100°C.

Model MEC

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UNITRON INVERTED Metallurgical Microscope, Model MEC: Many of the features of the UNITRON Metallograph U-11, which are connected with visual observation of opaque specimens, are included in this compact unit. Think of the time which can be saved in your laboratory by providing each metallurgist with one of these handy, inexpensive units for use at his desk. Model MEC is also ideal for use together with a polisher or microhardness tester.

- Standard optics include 4 parfocal objective lenses: 5X, 10X, 40X, 100X oil immersion on revolving nosepiece; 3 eyepieces: P5X, Micrometer 10X, Ke15X, all coated. Magnification range 25-1500X.
- Vertical illuminator with iris diaphragm. Transformer housed in microscope base. A microswitch on the base provides an extra high intensity for photography.
- Binocular model has provision for attaching 35mm camera to microscope base. A 35mm camera attachment is available to attach to the eyepiece tube of the monocular model.
- Calibrated square mechanical stage with calibrated rotatable stage plate.
- Calibrated polarizing apparatus, 5 filters, dustcover, cabinet, etc. all included.
- Additional accessories available at extra cost include: 35mm camera attachment; K20X eyepiece for 2000X; transmitted-light accessories for transparent specimens; vacuum heating stage.

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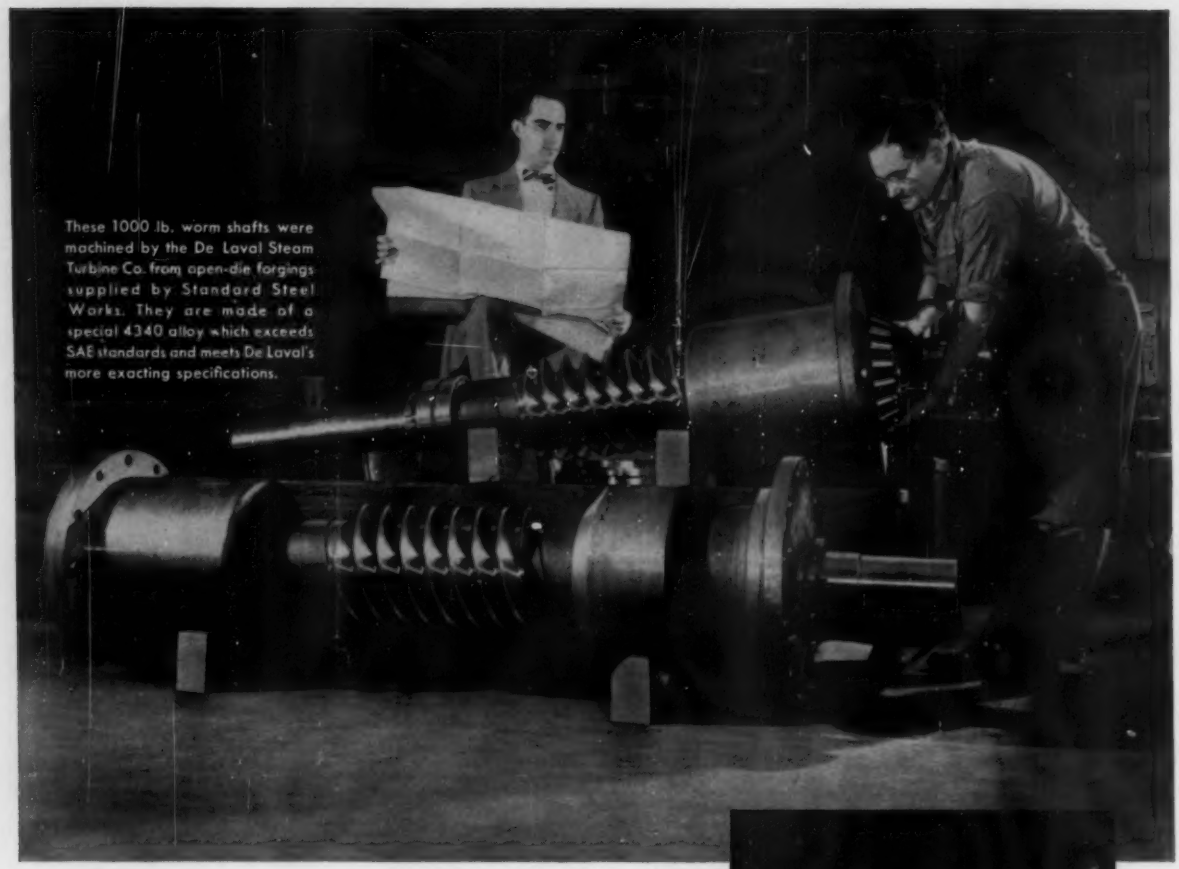

These 1000 lb. worm shafts were machined by the De Laval Steam Turbine Co. from open-die forgings supplied by Standard Steel Works. They are made of a special 4340 alloy which exceeds SAE standards and meets De Laval's more exacting specifications.

"It used to take us 12 weeks to get the required forgings for these worm shafts. We now get them in 6 weeks —from Standard Steel Works"

We accommodate De Laval's Mr. Schwarz in two ways so as to give him the service he wants: (1) We keep ingots and billets of the special high quality steel De Laval demands on order point—we can meet even the largest requirements on short notice; (2) each forging is tested and inspected—the product of complete and precise quality control. Mr. Schwarz knows he can expect not only service, but also quality when he orders forgings and castings from us.

Mr. Schwarz is just one of many industrial executives who have been impressed with the extra *service* we enjoy rendering. Not a month goes by that De Laval doesn't come to us with some special request which we can meet, and cheerfully. And hardly a day goes by that one of our many customers doesn't put our boast of personalized service to the test. Why don't you let us handle your next forging or casting requirement. You'll appreciate our service as well as our know-how. Write Dept. 3E.

"It's not unusual for me to be invited out on the floor to talk with the men who are actually making castings and forgings for us. In my opinion it's the personal interest which the men at Standard take in a customer's order that lies behind the consistently excellent service they render," *says E. T. Schwarz, Director of Purchasing, De Laval Steam Turbine Co., Trenton, N.J.*

Standard Steel Works Division

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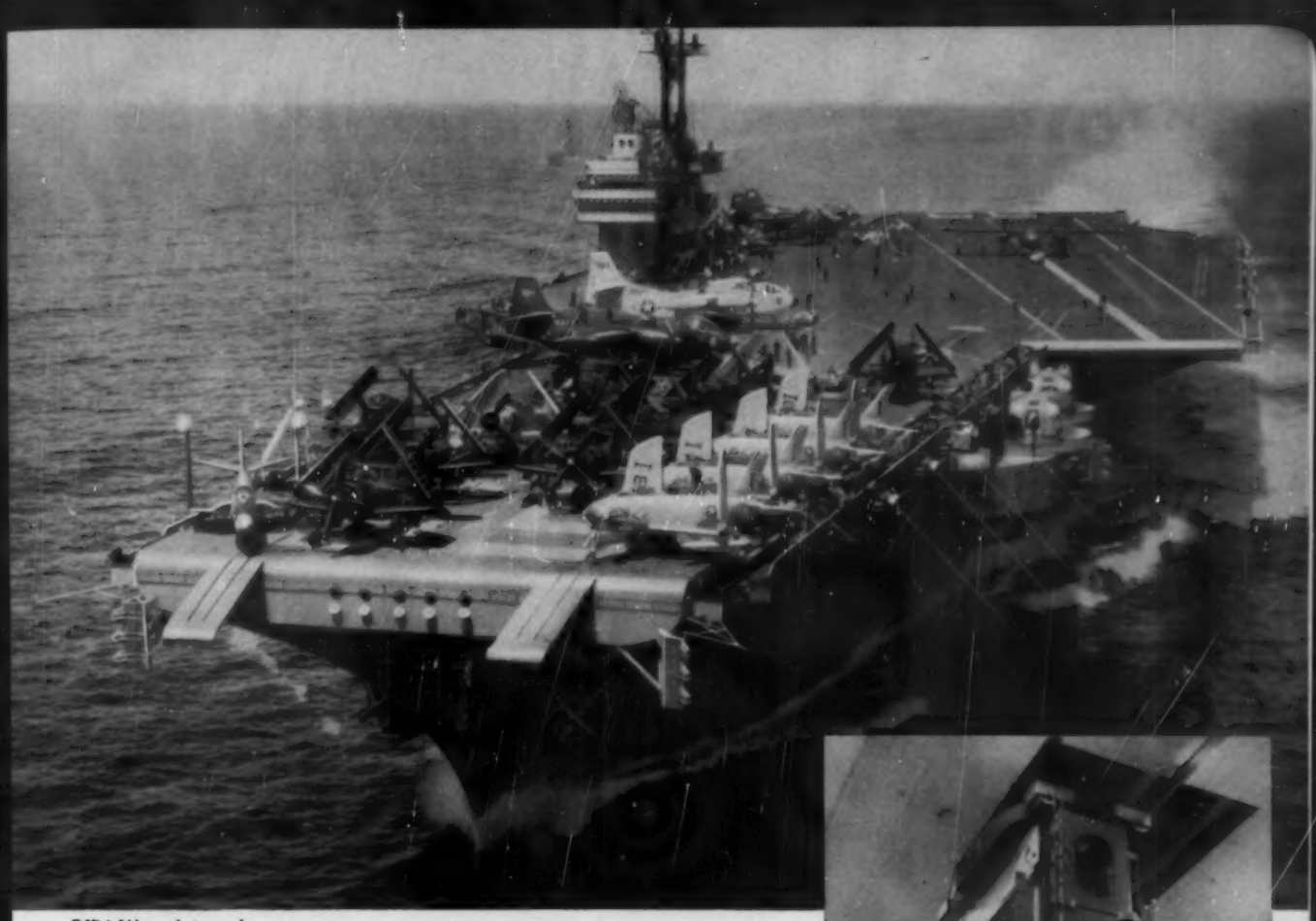


Official Navy photograph

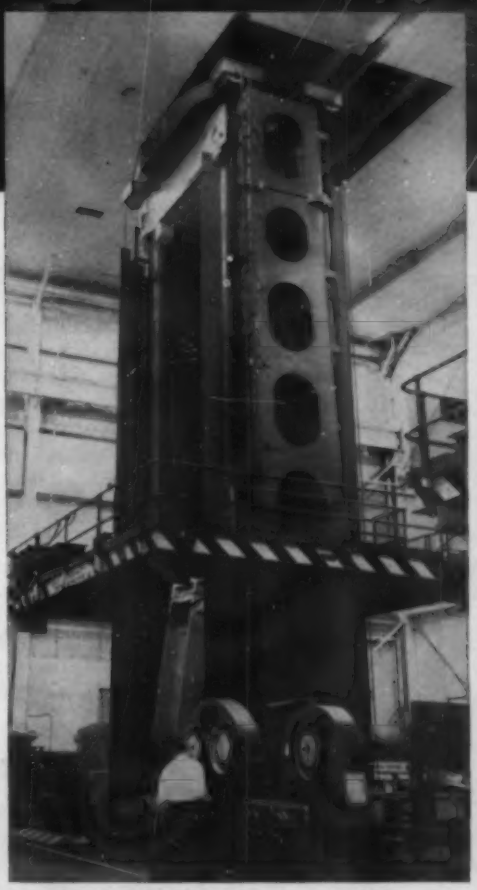
A BALDWIN TESTING MACHINE WAS USED TO FRACTURE THE ANCHOR CABLE OF A CARRIER

For the best in testing, see Baldwin first

Philadelphia Navy Yard's 5-million-lb. Baldwin BTE Universal Testing Machine was used to actually fracture a link similar to those in the anchor cable of the U.S.S. *Forrestal*, newest giant carrier. The Navy has long recognized the importance of testing in its continuing research and development program. In this, Baldwin plays an important role.

For precision performance in production and quality control testing in the shop, or for research testing in the laboratory, Baldwin offers a complete line of testing equipment. The BTE universal testing line, for example, includes many models, standard, semistandard, and specially engineered. Capacities run as low as 10,000 lb. maximum capacity, as high as 5 million lb.

Whatever your testing problem, compression, tension, creep, fatigue, impact or torsion, bring it to Baldwin. Or write today and ask to have a Baldwin representative call on you.



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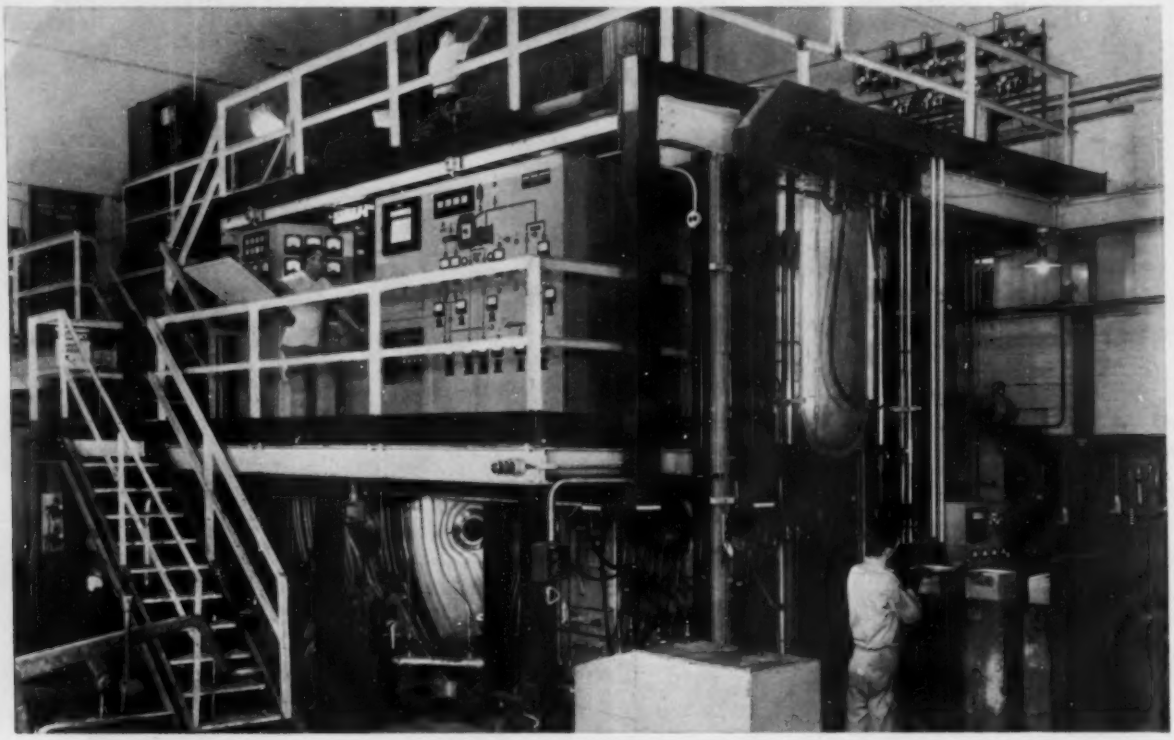
Electronics & Instrumentation Division

Waltham, Mass.

Testing machines • SR-4® strain gages • Transducers

At Last! Proof That Vacuum Furnaces Have Grown Up



Two miles of wire and one-half mile of copper tubing were used in the construction of this vacuum furnace by National Research Corporation for Vacuum Metals Corporation, Syracuse, New York. Equipped with air locks and hydraulic controls, it permits casting and removing 3000 pound ingots without breaking vacuum. "Watch-dog" timers and interlocks guard against operator error and make the operation of this furnace almost automatic.

Facts About the Triumphant Performance of
The World's Largest High Vacuum Induction Furnace

This NRC unit, built for Vacuum Metals Corporation, set a new standard of performance for large high vacuum furnaces. Not only is it the world's largest and most automatic vacuum induction furnace, but it successfully produced a 2200 pound ingot *on the very first try*. It is today making melts up to 3000 pounds in a wide variety of alloys and ingot combinations.

From their own sad experience many vacuum melters agree that it is unusual for *any* vacuum furnace to perform properly, right from the start. It is unheard of for a "first-of-its-kind" furnace of such size and complexity. Among its pioneering features are operation of the induction coil at 800 volts, coaxial power leads, provision for flooding with argon in less than 11 seconds, pictorial control panel, and joy-stick controls.

You can expect completely satisfactory performance like this from any NRC vacuum furnace — large or small — induction, arc, or resistance. From the 4 pound NRC Model 2904B to production-sized furnaces, they all will give you maximum results with a minimum expenditure of man hours. That's because of what we've learned from building and operating more high vacuum furnaces than any other organization in the world. Send coupon below for more information.

We Need
FIVE ENTHUSIASTIC ENGINEERS
To Help Us Keep Growing.

Mechanical, electrical and chemical engineers who honestly enjoy solving novel problems in brand new fields are offered new responsibilities and more stimulating work. Write Mr. David Tobin or call De 2-5800.

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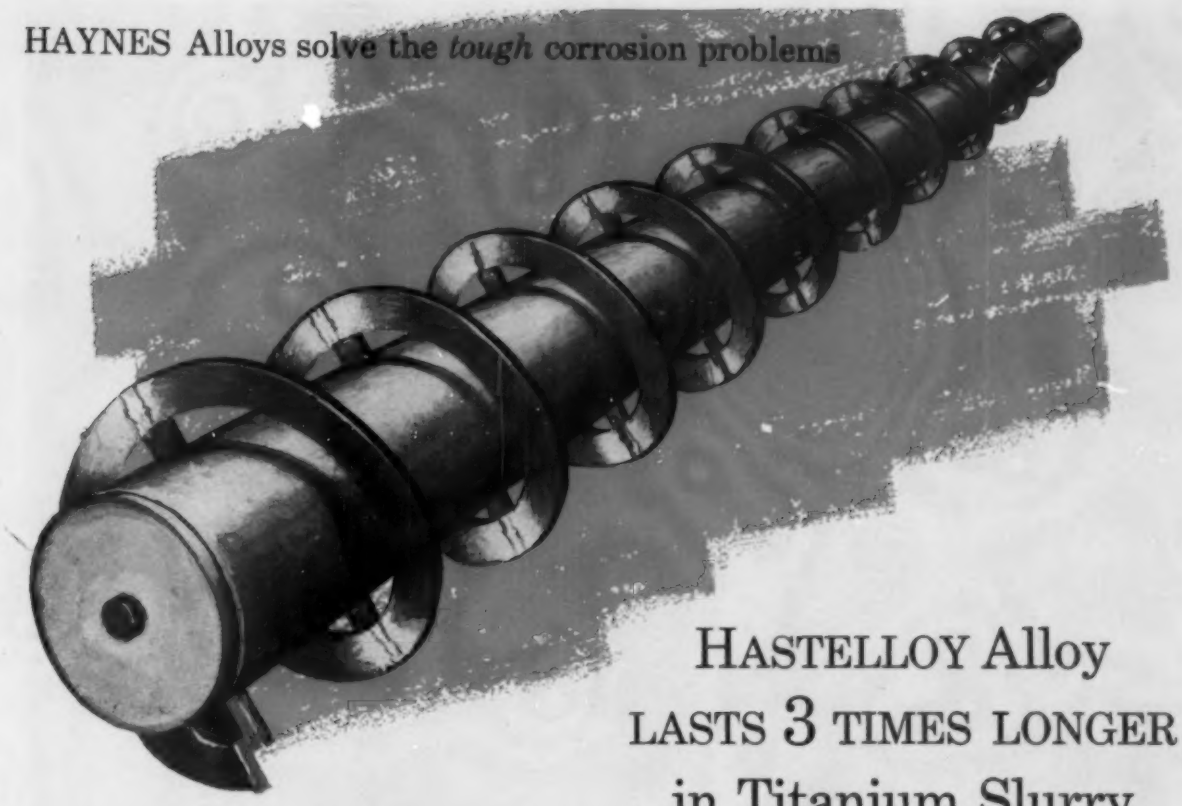
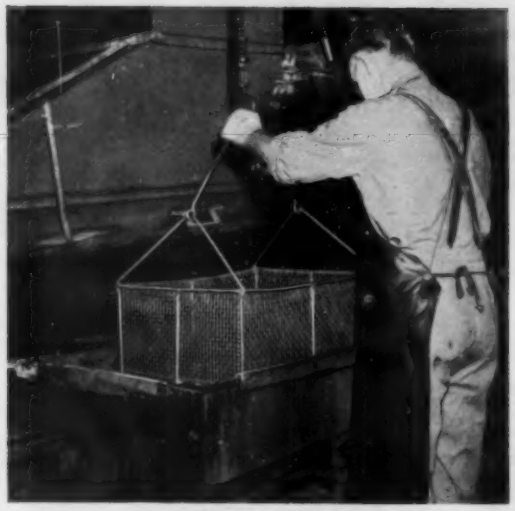
HAYNES Alloys solve the *tough* corrosion problems



HASTELLOY Alloy LASTS 3 TIMES LONGER in Titanium Slurry

Feed screws made of HASTELLOY alloy B last from 5 to 6 years while moving titanium slurry into kilns. This is three times longer than the service life of feed screws made of other alloys and used under the same severely corrosive conditions.

Handling titanium slurry is just another example of the many uses of HAYNES corrosion-resistant alloys. These nickel-base materials also have unusual resistance to the hot mineral acids, strongly oxidizing salts, and powerful gaseous oxidants. For full details, write for descriptive literature.



Six Years in HCl at 140 deg. F. is another example of how HASTELLOY alloys are solving Metalworking's corrosion problems. This pickling tank outlasted previously used materials by 4 to 1.

HAYNES STELLITE COMPANY

A Division of Union Carbide and Carbon Corporation

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Utica technician viewing a meltdown of Udimet 500—a new vacuum melted alloy in the high temperature field.

birth of a superalloy

Vacuum melted alloys, as developed by the Utica Metals Division of Kelsey-Hayes, provide extreme cleanliness; maximum chemical uniformity. They are superalloys, developed to withstand stresses and temperatures generated at supersonic speeds.

Utica, backed by the full resources and combined facilities of the Aviation Divisions of Kelsey-Hayes, is better equipped than ever before to serve the military, aviation and other industries.

VACUUM MELTING
provides these properties

- *High temperature corrosion resistance*
- *Increased ductility*
- *Extreme cleanliness*
- *Precise chemical control*
- *Longer stress-rupture life*
- *Increased tensile strength*
- *Better fatigue resistance*
- *Greater yield strength*
- *Greater impact resistance*
- *Greater creep properties*

UTICA METALS DIVISION OF KELSEY-HAYES

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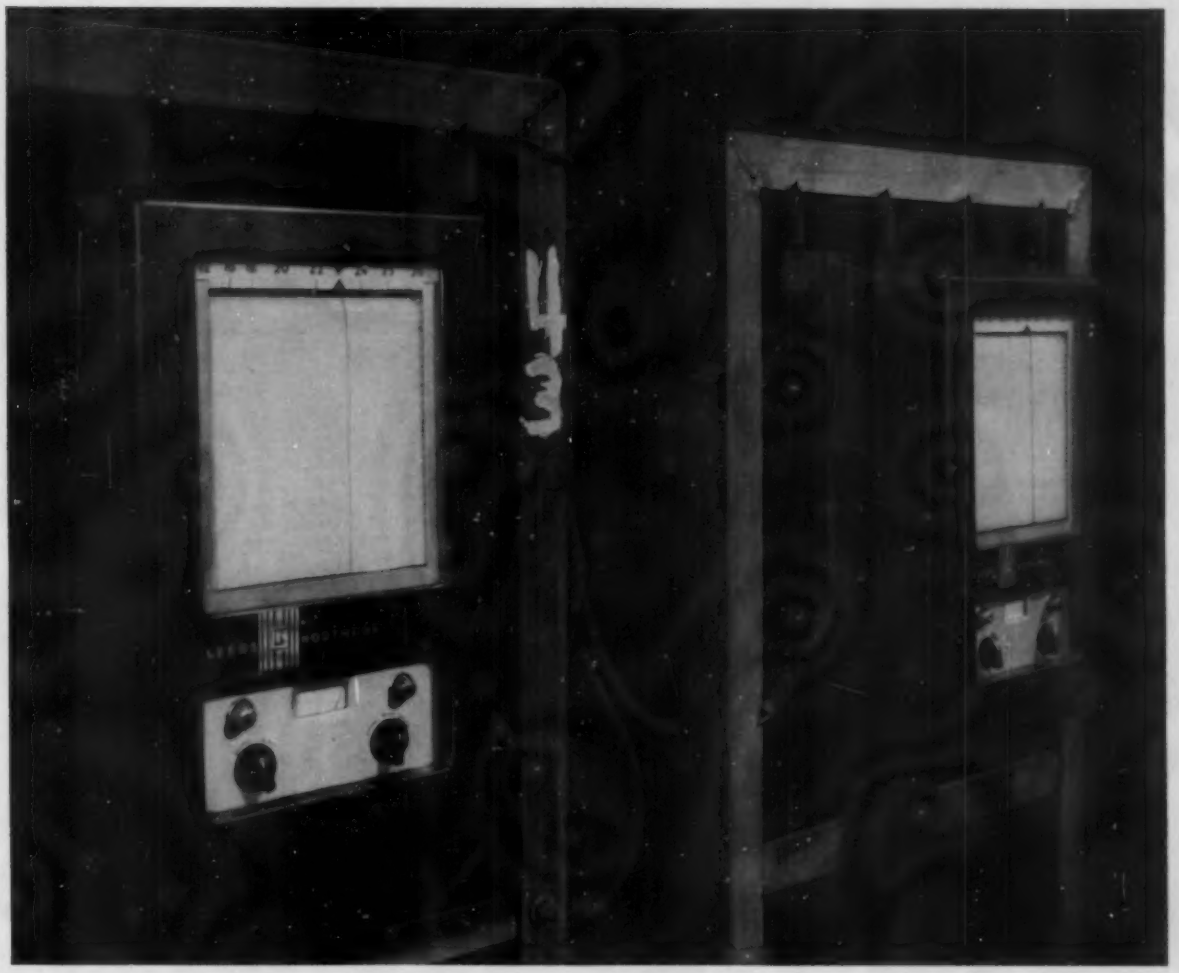

30 STEAM HAMMERS

can't shake Speedomax® H off control

In the heart of the Chicago steel area, Speedomax H 3-Action P.A.T. recording controllers are helping Standard Forgings Corp. turn out quality forgings which range in size from 5 lb. blanks to railroad axles weighing about ½ ton. Subjected to constant and severe vibration from 30 steam hammers and 60 presses for 24 hours a day, 5 days a week, 13 Speedomax H instruments (with five more waiting installation) have been controlling furnace temperatures for over a year with only such routine maintenance as chart changing, etc. And work temperature is held constant within ± 10 F. In both respects, this represents far better performance than the company has experienced before.

In addition to being assured of the correct temperature for each heat, Standard Forgings has also realized the following more tangible benefits since installing Speedomax H: (1) doubled refractory life, (2) reduction in scale with corresponding reduction in bottom cleaning from twice a week to once in two weeks, and (3) fuel savings of 50-75 gallons of oil per shift. Savings realized in increased furnace efficiency alone paid for the instrumentation in a short time.

Perhaps Speedomax H can help solve your temperature problems. For further information, contact your nearest L&N office or write 4927 Stenton Avenue, Philadelphia 44, Pa.

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- Increases brightness range 10%
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CADALUME simplifies the cadmium plating process—makes it profitable for job shops and plating plants.

LONGER LIFE	80,000 AMP HOURS A GALLON
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Long-life plus economy is the keynote of CADALUME. Once a new bath is made ready with CADALUME MAKE-UP BRIGHTENER—or an existing bath converted —*all* plating is done with single-solution, stable CADALUME BRIGHTENER. Keep your cadmium plating costs low. Get all the facts. Write for the New Cadalume Technical Manual—today. **Hanson-Van Winkle-Munning Company, Matawan, New Jersey. Offices in principal cities.**

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WHO FORGES THE TOUGH ONES? *& machines them, too*

Suppose you had to have a coupling, such as the one above for a ship shaft, machined so accurately that the two parts fit to each other with 90% surface contact. Where would you go to have the forging and machining done? You know, there aren't many companies that can make forgings that big, and there aren't many that can do such precision-finish machining. But we are a company that does both!

A job such as this is not a "special" with us, for we've been producing big forgings for over 40 years. And the thing our customers like best about us is that we can handle the whole job—from basic steel to finished product—all in one completely integrated plant. We'd welcome the chance to quote on your next job for big machined forgings—and to demonstrate the answer to "who forges and machines the tough ones . . . best?"

NATIONAL FORGE
AND ORDNANCE COMPANY

IRVINE (WARREN COUNTY), PENNSYLVANIA

To see more of "the tough ones," and the machinery they're made on, write for Bulletin NFO.

Vacuum-melted alloys stay stronger, more ductile at high temperatures

Where engine temperatures exceed 1200°F, for example, vacuum-melted alloys add high strength without loss of ductility. Reason? In vacuum-melting, metals of unprecedented composition control and purity are standard. Inclusions are almost totally absent; mechanical and physical properties are higher and more uniform in all directions, and also from heat to heat. Furthermore, many alloys are readily made under the precise control of vacuum melting that are otherwise impossible or uneconomical to make at all.

Vacuum Metals Corporation, Division of Crucible Steel Company of America, is the first and largest producer of vacuum-melted metals. It is now melting heats up to 3000 pounds. Large sections and a wide variety of alloys are available to the aircraft industry. We would like to work with you on metals problems which vacuum-melted alloys may solve. Please write, giving as much detail as possible, to *Vacuum Metals Corporation, Division of Crucible Steel Company of America, P. O. Box 977, Syracuse 1, N. Y.*

Vacuum-melting is adding new performance to these metals. Do you have an application that may benefit from their use?

- High temperature alloys
- Bearing steels
- Tool steels
- High strength alloy steels
- Low alloy steels for springs
- Stainless steels
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- Nuclear reactor materials
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VMC®

VACUUM METALS CORPORATION

Division of Crucible Steel Company of America

NEW FROM GENERAL ELECTRIC . . .

52% MORE USABLE PANEL SPACE

GENERAL ELECTRIC'S NEW PYROMETER SAVES SPACE WITH PRINTED CIRCUITS AND MINIATURE COMPONENTS

A new pyrometer that fulfills industrial heat treating requirements of close reproducible control at low cost is now available from General Electric.

THE SMALLER SIZE of the new HP-30 Series Pyrometer means that valuable panel space can be conserved. The size reduction of the instrument was made possible through use of printed circuits, high strength magnet material, and miniature components.

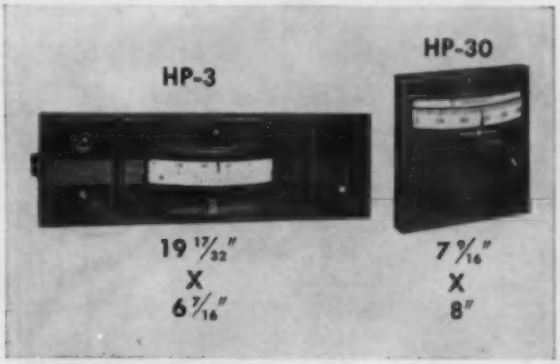
AN EXCLUSIVE FEATURE of General Electric's new pyrometer is automatic lead length compensation. The HP-30 offers lead length compensation up to 25 ohms in low ranges and 90 ohms in higher ranges.

HIGH ACCURACY and control sensitivity are maintained at levels associated with General Electric's HP-3 Pyrometer. The new instrument features ±.5% accuracy and .1% to .5% sensitivity adjustment.

EASY CONNECTIONS are possible with the HP-30 because it features knockouts on the top and side of the controller case. Electrical connections may be made to the front or back of a printed circuit board.

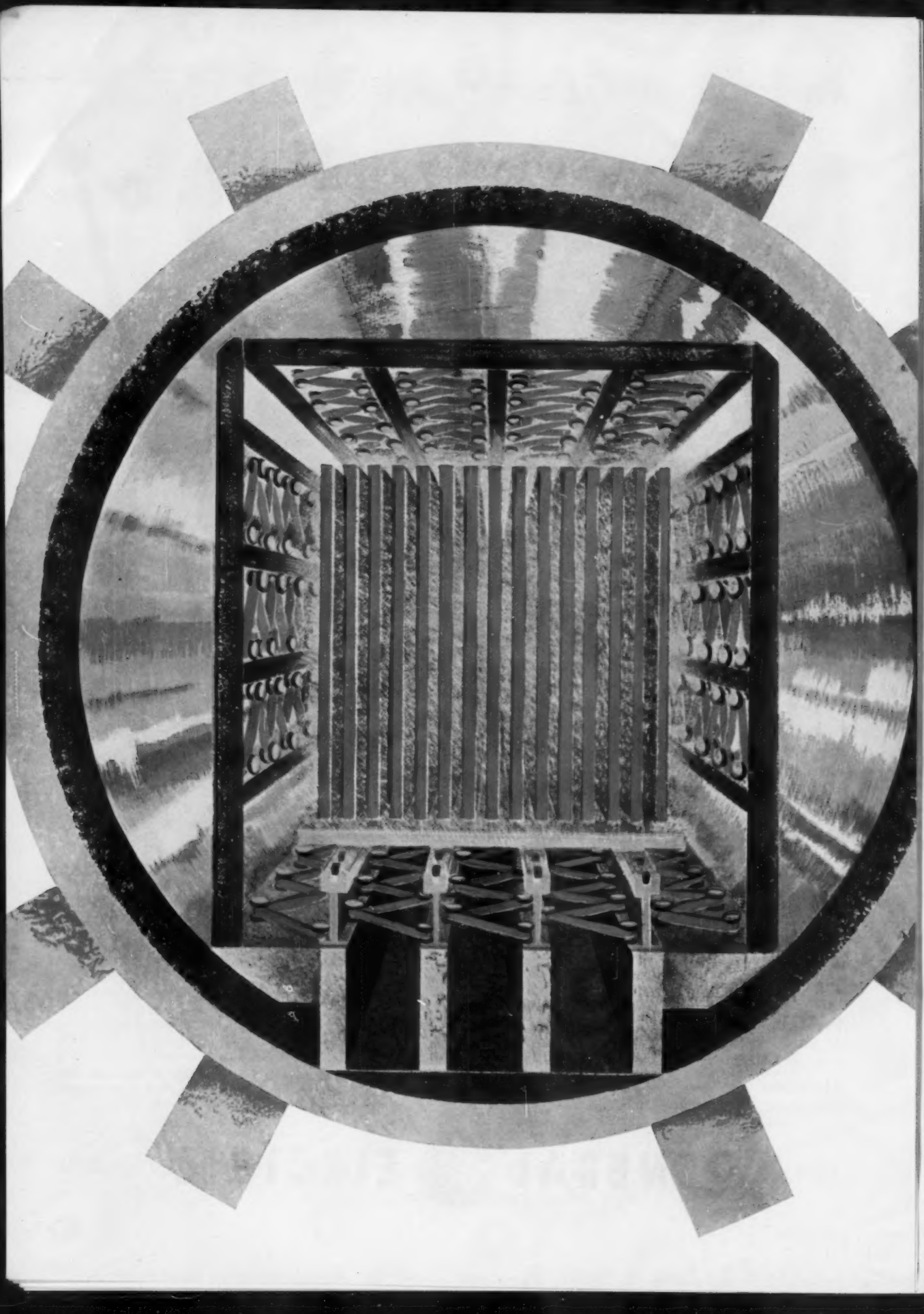
FLEXIBILITY of the new pyrometer allows flush or surface mounting, interchangeable control forms, and range changes that can be made in the field. In addition to six basic control forms, special variations to solve specific control problems are available on request.

For further information, write to Section 587-8, General Electric Company, Schenectady 5, N. Y., or contact your nearest General Electric Apparatus Sales Office.



COSTLY PANEL SPACE can be saved with the new HP-30—companion to the widely accepted HP-3. Both General Electric instruments feature high accuracy and close reproducible control.

GENERAL ELECTRIC

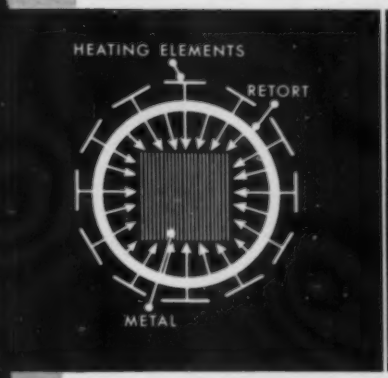


New Westinghouse Kold-Retort furnace speeds vacuum heat-treating of titanium... eliminates retort problems

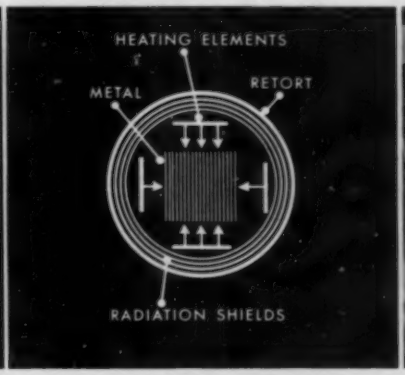
Kold-Retort® furnace design is a bold, original step to increase heating and cooling rates and lower production costs in processing reactive alloys.

It started with setting aside conventional furnace concepts. By co-ordinating vacuum equipment research with design and operating experience at Mallory-Sharon Titanium Corp., Westinghouse engineered more effective heat application.

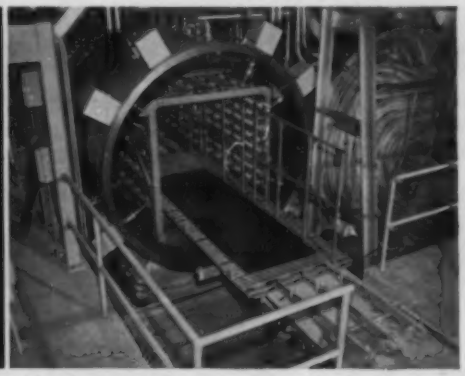
Conventional vacuum furnaces (A-below) depend upon radiation of heat to the retort which then radiates it to the charge. Kold-Retort design (B) places the heating elements inside the retort and uses radiation shields for insulation. Hence, there are no replacement costs for retorts distorted by frequent heating cycles.



A-*Conventional furnace design*



B-*Kold-Retort furnace design*



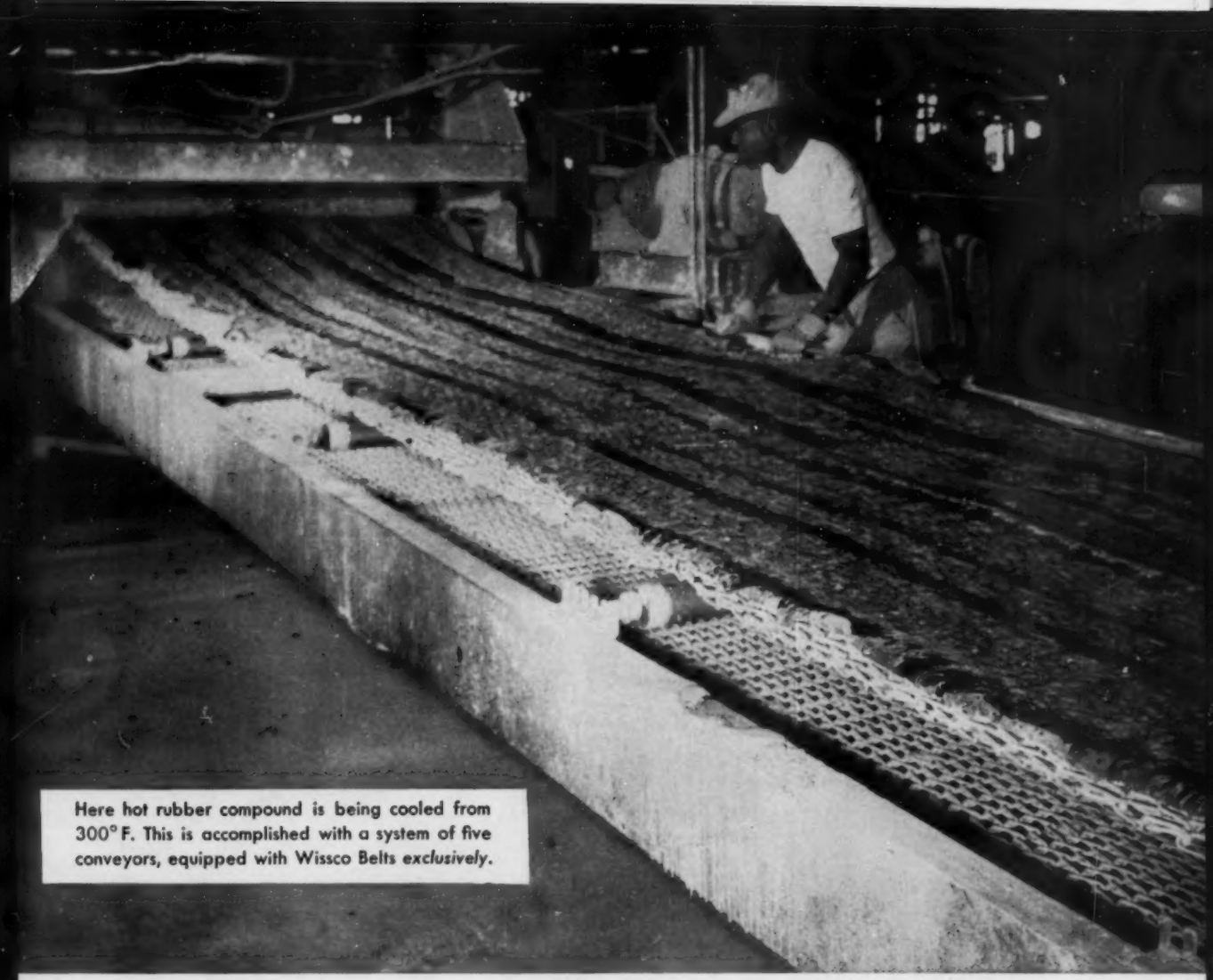
C-*Kold-Retort furnace in operation at Mallory-Sharon Titanium Corp., Niles, O.*

Kold-Retort furnaces (C) have been built with charge capacities up to 4 x 4 x 12′ long and for temperatures up to 3200°F. Because the retort remains cold, there are no size limitations. Preliminary work has already been done on a unit 20 x 12 x 50′ long for brazing complete aircraft wings at 2150°F.

This new Westinghouse design can be a practical answer to lower your costs in vacuum annealing and degassing of titanium and zirconium alloys, bright annealing of stainless steels, and in high-temperature brazing of intricate structures. It's another example of the way Westinghouse helps you Power-Up... to get better production and profit from your electrical dollar. Write Westinghouse Electric Corporation, Industrial Heating Division, Meadville, Pa.

J-10467

YOU CAN BE **SURE**... IF IT'S Westinghouse



Here hot rubber compound is being cooled from 300° F. This is accomplished with a system of five conveyors, equipped with Wissco Belts *exclusively*.

FAMOUS NAMES

ride on WISSCO BELTS

Goodyear Tire and Rubber Company • Topeka, Kansas

Goodyear, a name long known for top-quality rubber products, has been using Wissco Belts for cooling operations in its Topeka, Kansas, plant for more than a decade.

Each belt in this system handles over 12,000 pounds of hot compounded rubber product per hour . . . 23¼ hours a day . . . six or seven days a week. With the average belt service having proved to be two years, this means that *each* belt conveys more than *17 million* pounds of rubber during its lifetime.

Years before the Topeka plant was opened in 1945, Goodyear had been testing, evaluating and using Wissco Belts in its Akron plant—with uniformly good results. No wonder then, for the past twelve years, Goodyear has specified *only* Wissco Belts for its Topeka cooling operations.

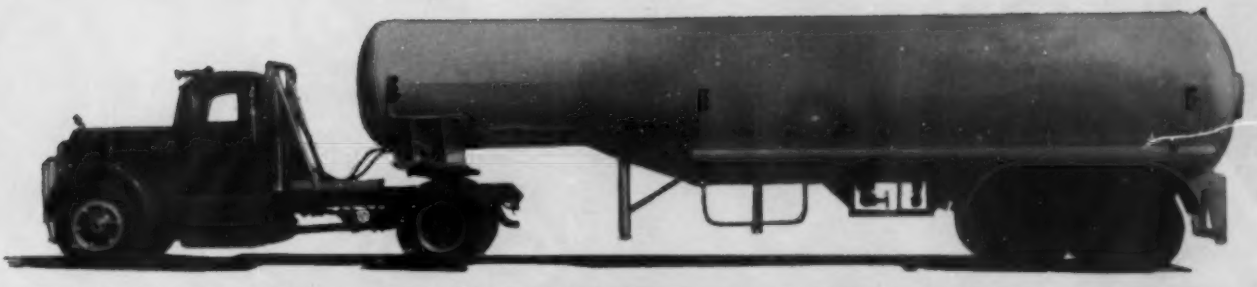
As with Goodyear, Wissco Processing Belts are the choice of many famous names in industry—leaders in their fields. If you are not already a Wissco Belt user, it'll pay you to get full details on how these efficient and economical belts can help you in your own operations.

THE COLORADO FUEL AND IRON CORPORATION
Denver and Oakland
WICKWIRE SPENCER STEEL DIVISION
Atlanta • Boston • Buffalo • Chicago • Detroit • New Orleans • New York • Philadelphia
CF&I OFFICES IN CANADA: Montreal • Toronto

CF&I **WISSCO BELTS**

PRODUCT OF WICKWIRE SPENCER STEEL DIVISION
THE COLORADO FUEL AND IRON CORPORATION

4632



PAYLOAD INCREASED 500 GALLONS in new LPG tank truck

PRESSURE VESSEL ON WHEELS FEATURES
"T-1" STEEL CONSTRUCTION

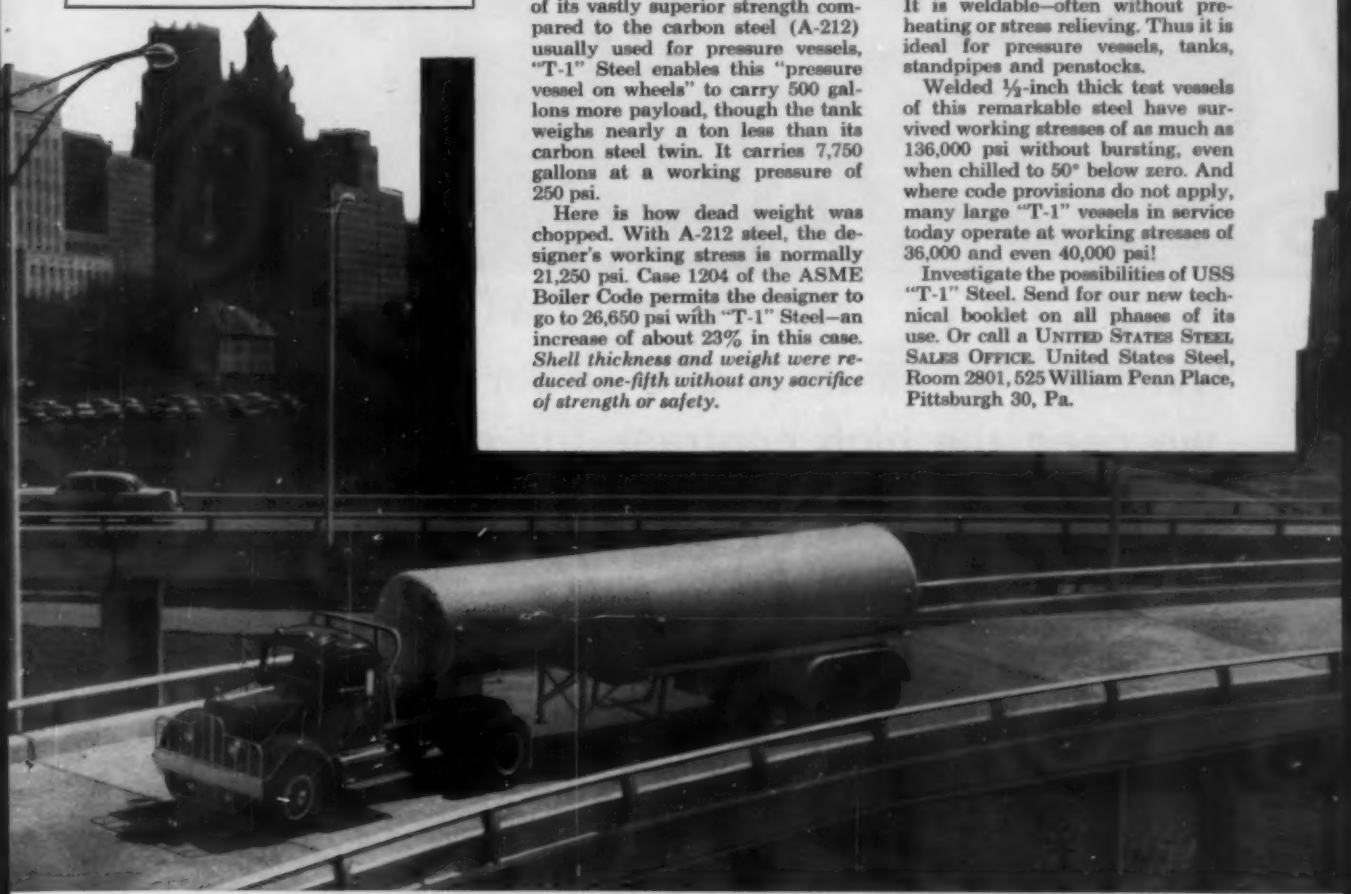
THE TANKER shown here is an important "first"—it is the *first* LPG trailer tank to be built of "T-1" Constructional Alloy Steel. Because of its vastly superior strength compared to the carbon steel (A-212) usually used for pressure vessels, "T-1" Steel enables this "pressure vessel on wheels" to carry 500 gallons more payload, though the tank weighs nearly a ton less than its carbon steel twin. It carries 7,750 gallons at a working pressure of 250 psi.

Here is how dead weight was chopped. With A-212 steel, the designer's working stress is normally 21,250 psi. Case 1204 of the ASME Boiler Code permits the designer to go to 26,650 psi with "T-1" Steel—an increase of about 23% in this case. *Shell thickness and weight were reduced one-fifth without any sacrifice of strength or safety.*

USS "T-1" Steel has, in addition to very high yield strength (90,000 psi minimum), exceptional toughness down to very low temperatures. It is weldable—often without preheating or stress relieving. Thus it is ideal for pressure vessels, tanks, standpipes and penstocks.

Welded ½-inch thick test vessels of this remarkable steel have survived working stresses of as much as 136,000 psi without bursting, even when chilled to 50° below zero. And where code provisions do not apply, many large "T-1" vessels in service today operate at working stresses of 36,000 and even 40,000 psi!

Investigate the possibilities of USS "T-1" Steel. Send for our new technical booklet on all phases of its use. Or call a UNITED STATES STEEL SALES OFFICE. United States Steel, Room 2801, 525 William Penn Place, Pittsburgh 30, Pa.



UNITED STATES STEEL CORPORATION, PITTSBURGH • COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO • TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS, COAST-TO-COAST • UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS "T-1" CONSTRUCTIONAL ALLOY STEEL

"USS" and "T-1" are registered trademarks.

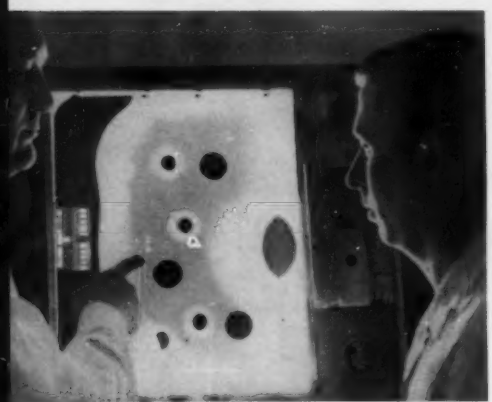
SEE The United States Steel Hour. It's a full-hour TV program presented every other Wednesday by United States Steel. Consult your local newspaper for time and station.

UNITED STATES STEEL

At the Wellman Bronze and Aluminum Plant, Chief Radiographer George R. Ritchey (left) and Bruce Sutherland, Du Pont Technical Representative, discuss a radiograph of a magnesium casting, made on Du Pont film.

"With lighter castings and closer tolerances, we need the high contrast and excellent detail of Du Pont 506 N. I. F.* x-ray film"

Chief Metallurgist Robert C. Boehm, Wellman Bronze and Aluminum Company, Cleveland, Ohio, tells why:



At the illuminator, Chief Metallurgist Robert C. Boehm (left) examines an x-ray of a helicopter gear-box housing with Radiographer Ritchey.

"Ten years ago parts were designed to 40 per cent of a material's strength. Now, with the lighter weight and higher safety factor required for aircraft, parts are designed much closer to maximum strength. Obviously, the closer we come to maximum stress, the more important it is that we are able to detect the smallest internal defects easily and quickly by x-ray examination.

"Du Pont 506 x-ray film gives us the sensitivity we need; it has high contrast, fine grain and excellent detail. It provides a wide exposure latitude, consistency and complete reliability."

Since several hundred sheets of x-ray film are run in Wellman's plants every day, they cannot afford the luxury of individual handling of the films. "The ruggedness and resistance to scratching and abrasion of Du Pont 506 are musts with such volume processing," says Mr. Boehm. He concludes: "Our skilled radiographic department demands that its x-ray film meet the rigid specifications of our quality control department."

*N. I. F.—Non-Interleaved Film

DISTRICT OFFICES

Atlanta 8, Ga.	805 Peachtree Bldg.
Boston 10, Mass.	140 Federal Street
Chicago 30, Ill.	4550 Touhy Ave., Lincolnwood
Cleveland 16, Ohio	20950 Center Ridge Road
Dallas 7, Texas	1628 Oak Lawn Avenue
Los Angeles 38, Calif.	7051 Santa Monica Blvd.
New York 11, N. Y.	248 West 18th Street
Philadelphia, Pa.,	308 E. Lancaster Ave., Wynnewood
Export	Nemours Bldg., Wilmington, Delaware

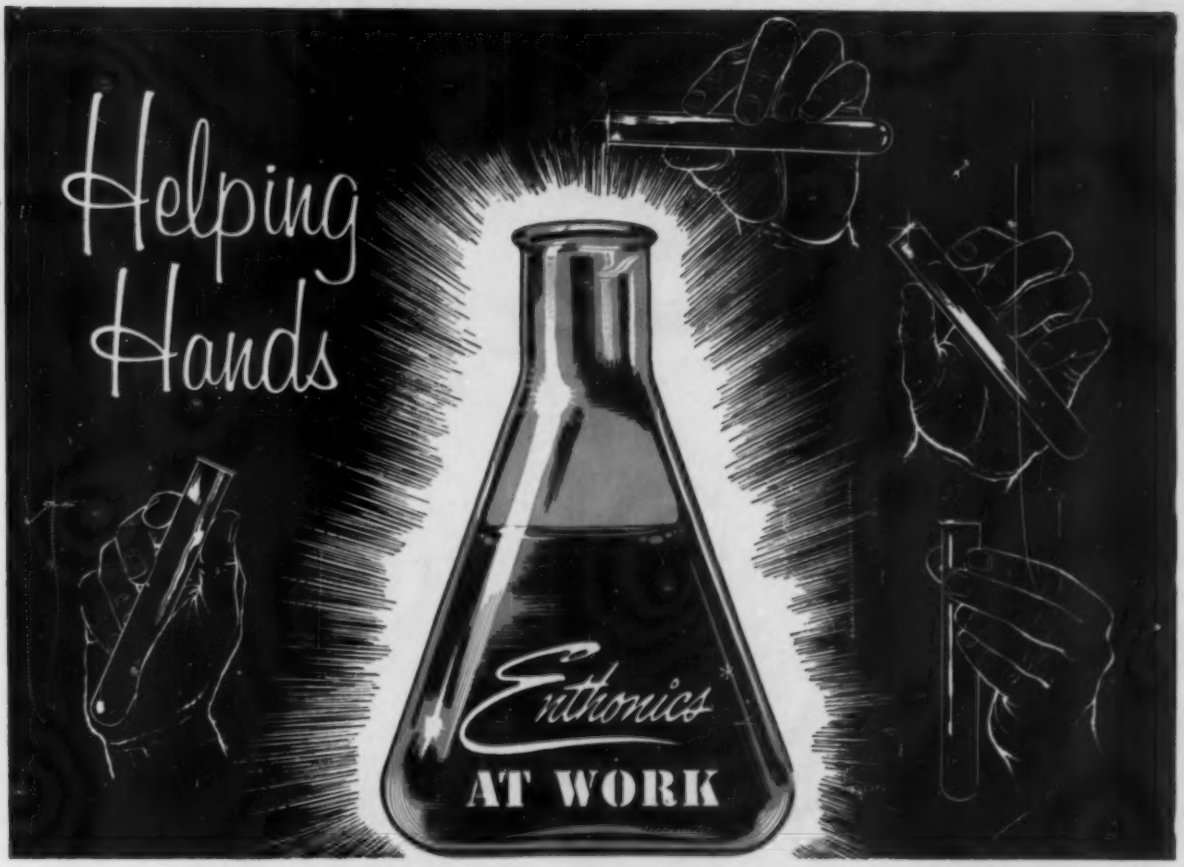
In Canada: Du Pont Company of Canada (1956) Limited, Toronto

DU PONT X-RAY PRODUCTS

Films • "Patterson" Screens • Chemicals

DU PONT
REG. U. S. PAT. OFF.

Better Things for Better Living . . . through Chemistry



FROM THOUSANDS of TESTS . . .

. . . *come the solutions to your metal finishing problems.*

If *you* are looking for creative chemistry to supply new methods for the improvement of metal finishing, look to the leader – ENTHONE. Write for the answers to these problems, identifying them by number. If your specific problem is not listed, Enthone will gladly help to find the answer.

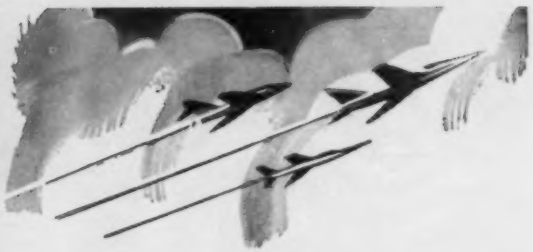
1. HOW TO BLACKEN copper, brass, zinc, steel and other metals to meet U.S. Government specifications.
2. HOW TO STRIP NICKEL from steel without etching the steel.
3. HOW TO STRIP NICKEL from copper and brass without attacking the part.
4. HOW TO SHED WATER from metals to prevent staining or spotting during drying.
5. HOW TO TRAP FUMES from hot sulfuric acid pickles.
6. HOW TO STRIP SYNTHETIC ENAMELS from aluminum and other metals without attacking the metal.
7. HOW TO CLEAN AND REMOVE RUST AND OXIDES from steel in one operation without acids.
8. HOW TO RINSE AND DRY STEEL WITHOUT RUSTING, using cold or hot water.
9. HOW TO SHORTEN ALKALI CLEANING TIME for steel to 15 seconds.
10. HOW TO REMOVE SOLID DIRT AND OIL from metals.
11. HOW TO STRIP LEAD, TIN or soft solder from copper and brass with no etching.
12. HOW TO PLATE METALS upon aluminum.
13. HOW TO REMOVE EXCESS SILVER SOLDER chemically from silver brazed steel parts.
14. HOW TO MAKE PAINT STICK to brass and zinc.
15. HOW TO SOLVENT-CLEAN parts and assemblies with cold non-hazardous solvent.
16. HOW TO OVERCOME CHROMIC ACID CONTAMINATION in cleaners.
17. HOW TO PREVENT STAINING of chromium plate.
18. HOW TO GIVE ZINC AND CADMIUM high salt spray resistance.
19. HOW TO COLOR ALUMINUM in one operation.
20. HOW TO STRIP METAL COATINGS from zinc die castings.

* *The Scientific Solution of Metal Finishing Problems.*

ENTHONE
INCORPORATED

442 ELM STREET, NEW HAVEN 11, CONNECTICUT

Metal Finishing Processes • Electroplating Chemicals



FORGING

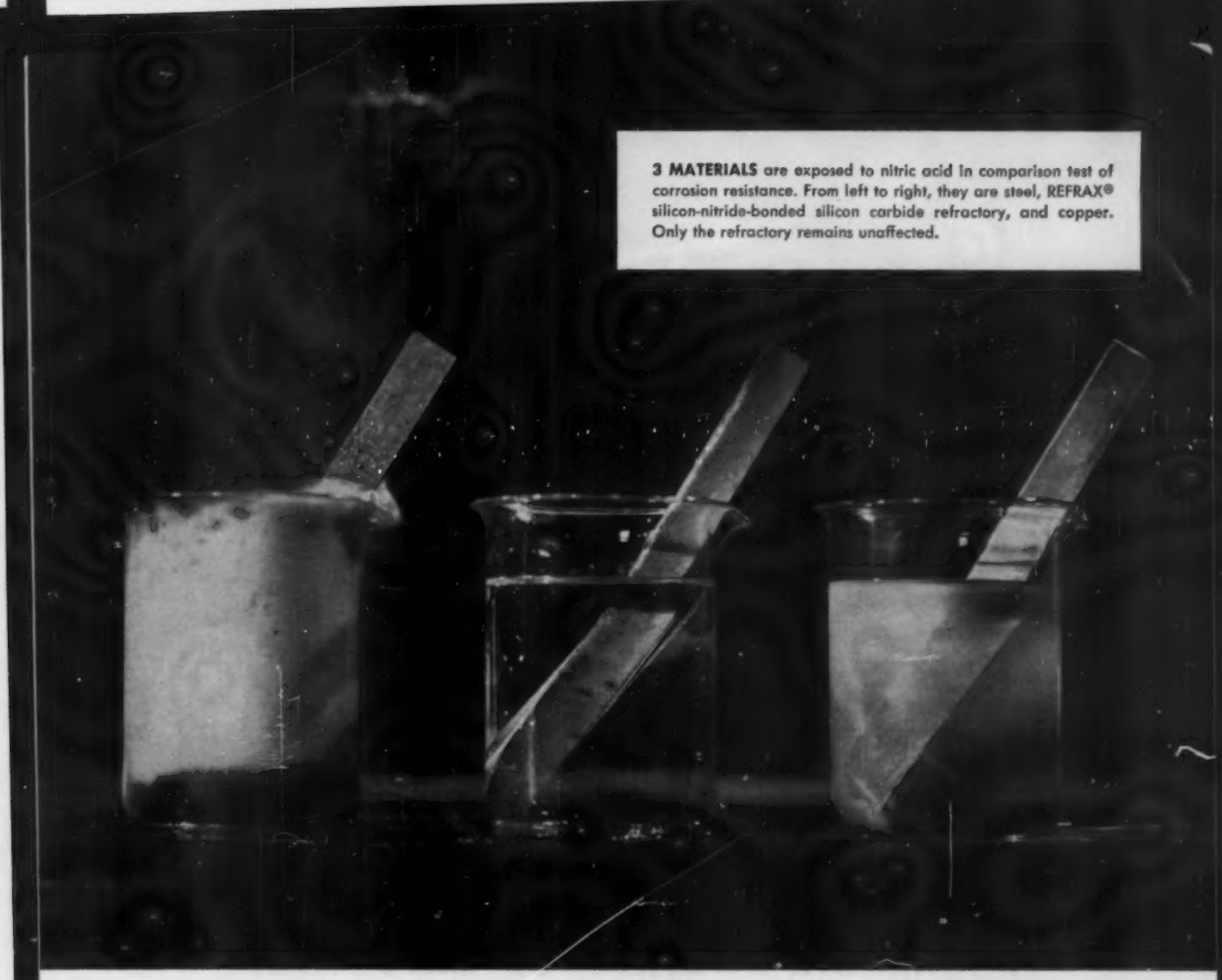
Air Superiority for National Defense

A complete prototype service for the design and production of jet engine blades is ready to work for you at the Metals Processing Division of Curtiss-Wright. One of the most experienced blade producers in the industry – now turning out thousands of blades daily – the Metals Processing Division can contribute importantly at any stage of your operation . . . from blueprint through prototype . . . from processing of pilot quantities to full volume production.

The Division's precision controlled production means more accurate development now . . . smoother production later. Coordinated facilities for casting, forging, grade rolling, machining and extrusion round out the picture. Write today for qualified engineering consultation, without obligation.

78 GRIDER STREET

METALS PROCESSING DIVISION
CURTISS-WRIGHT
CORPORATION • BUFFALO, N. Y.



3 MATERIALS are exposed to nitric acid in comparison test of corrosion resistance. From left to right, they are steel, REFRAX® silicon-nitride-bonded silicon carbide refractory, and copper. Only the refractory remains unaffected.

Refractories for outstanding **corrosion resistance**

Wherever the possibility of chemical attack exists, it pays to consider refractories as materials of construction. The picture shows why. In numerous corrosive applications, CARBORUNDUM'S refractories are proving superior to other materials. They resist many highly basic substances as well as acids, acid slags and fluxes.

Typical applications are: linings in controlled atmosphere furnaces, pumps and pump parts handling molten aluminum, nozzles spraying corrosive *and* abrasive liquids, linings in muriatic acid furnaces, retorts for reducing and refining zinc ores, linings for glass tanks, etc.

But seldom is a refractory called upon to provide corrosion resistance alone. It may be required to transmit heat rapidly, resist thermal shock cracking, withstand abrasion, carry heavy loads, retain initial purity . . . whether at low or extremely high temperatures.

These properties are but a few of those found in super refractories pioneered by CARBORUNDUM. Among them, you are almost certain to find answers to your material selection problems. For help, fill in and mail this coupon today.

CARBORUNDUM
Registered Trade Mark

——————MAIL THIS COUPON TODAY——————

Refractories Division,
The Carborundum Company, Perth Amboy, N. J., Dept. M57

Please send me:

- ☐ Forthcoming issue of Refractories Magazine
- ☐ Bulletin on Properties of Carborundum's Super Refractories
- ☐ Here is a description of my corrosion problem. Can you help me?

Name_____ Title_____

Company_____

Street_____

City_____ Zone____ State_____

Available soon at lower prices . . .

A MILLION POUNDS OF ZIRCONIUM FOR INDUSTRIAL USE

By mid-1957 zirconium users can get 1,000,000 lbs. a year of the metal from a new U.S. Industrial Chemicals Co. plant at Ashtabula, Ohio. In a new, non-pyrophoric, non-hygroscopic platelet form U.S.I. zirconium has these advantages over the more familiar sponge metal: it eliminates safety problems in handling and shipping, and it permits a cleaner, safer melting operation.

Lower Price

Reactor grade will be priced at $4.75 to $6.50 a pound, depending on quantity. Commercial grade will sell at about $1.50 less. These low prices will be possible because U.S.I., as a prime producer of sodium metal, uses a semi-continuous sodium reduction process—the most economical production technique ever developed for reducing metallic chlorides.

Higher Quality

U.S.I. zirconium will offer users top quality, too. In the first place, U.S.I. starts with sodium, a higher purity raw material than the reducing agents commonly used in other processes. Then, the technique itself yields a product of higher purity and uniformity. Finally, in making its zirconium platelets U.S.I. virtually eliminates chloride, magnesium, sodium and hydrogen impurities.

Small quantities of commercial grade material are available for immediate delivery. To help you on applications U.S.I. has a staff of metal experts. Call Bill Greenleaf, Manager of Metals Department, for further information.

U.S.I. INDUSTRIAL CHEMICALS CO.
Division of National Distillers Products Corp.
99 Park Avenue, New York 16, N. Y.

THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

NATIONAL ENGINEERING SERVICE

on

Heat and Corrosion Resistant Castings and Fabrications

General Alloys Company products are backed by a national engineering service offering unexcelled mechanical and metallurgical Heat and Corrosion Resistant Alloys for all Defense and Industrial applications.

"There is no substitute for Experience"

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CLEVELAND 15, Ohio
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LOUISVILLE 7, Kentucky
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INDIANAPOLIS 8, Indiana
The George O. Desautels Co.
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Associated Steel Mills, Inc.
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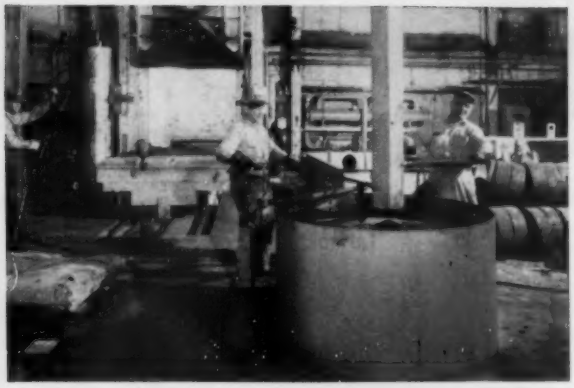
GENERAL ALLOYS COMPANY

405 WEST FIRST STREET **BOSTON, MASS.**

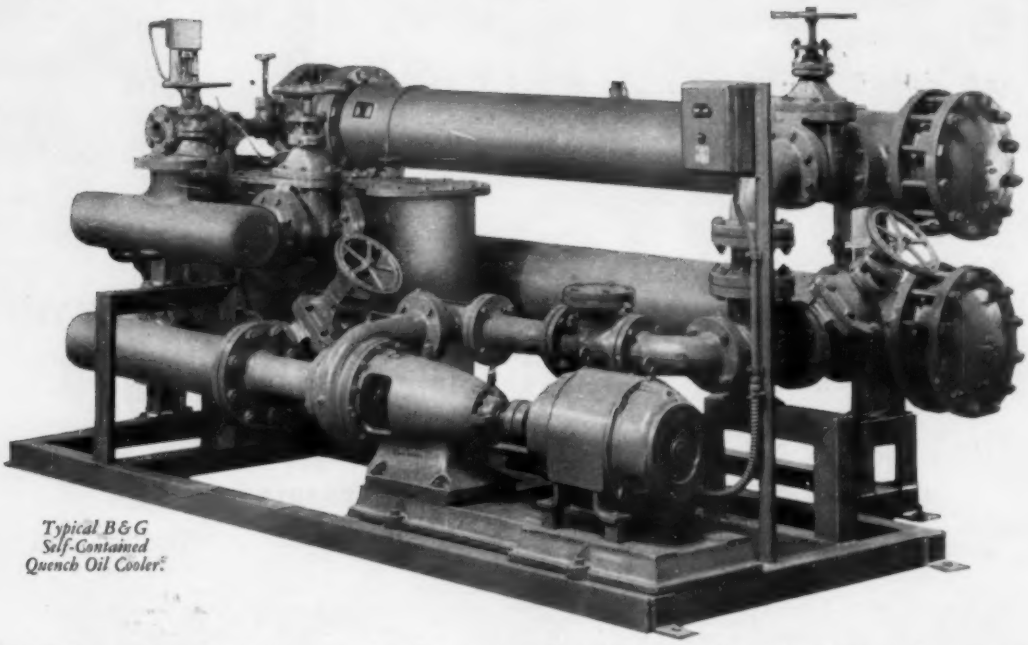
"OLDEST AND LARGEST EXCLUSIVE MFRS. OF HEAT & CORROSION RESISTANT CASTINGS"

GA ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION X-ite



COMPONENT PARTS OR SELF-CONTAINED UNITS FOR

Controlled QUENCH OIL COOLING



Typical B&G Self-Contained Quench Oil Cooler.

Controlled quenching of your heat-treated products can result in a substantial "inside profit"...by eliminating losses caused by excessive rejects.

B&G *Hydro-Flo* Oil Quenching Systems have demonstrated ability to maintain desired characteristics in the finished product. Heated metal is brought down from furnace temperature to the correct end degree with unfailing accuracy. Each batch is quenched under *identical* conditions, hence is *identical* in quality.

B&G *Hydro-Flo* Self-Contained Oil Coolers are complete packages...combining Coolers, Motors, Pumps, Strainers and all controls into single integrated units. Or, if you prefer, the component parts of a B&G *Hydro-Flo* Oil Cooling System may be purchased and assembled on the job. B&G Quench Tanks are also available...either in standard designs or built to your specifications. The B&G engineering staff is always available for consultation.

Send for Catalog and Simplified Selection Manual

Hydro-Flo*

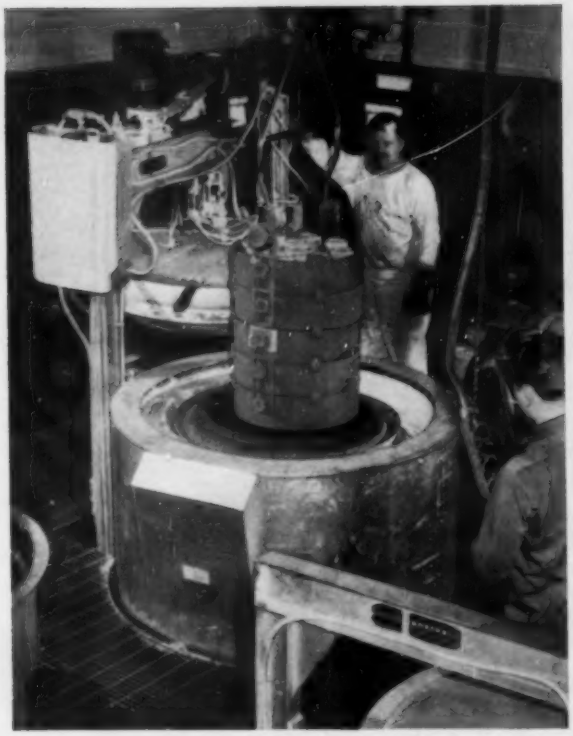
OIL QUENCHING SYSTEMS

BELL & GOSSETT COMPANY

Dept. EU-16, Morton Grove, Illinois

Canadian Licensee: S. A. Armstrong Ltd., 1400 O'Connor Drive, Toronto 16

*Reg. U.S. Pat. Off.



Repeatedly heated to 1830°F...

Repeatedly cooled to quench temperature...

Inconel alloy stack-type trays look "good-as-new" at 2000-hour mark

These lightweight Wiretex-made fixtures also push treating costs down 20% in same period

These pictures make it clear.

After 2000 hours of pit-type heat-treating service, these Inconel* nickel-chromium alloy trays fabricated by Wiretex for Fenn Mfg. Co., Newington, Conn., manufacturers of rolling mills and swagers, are practically undamaged.

No serious attack from high heat. From thermal shock. From furnace atmospheres. From oxidation. From heavy loading. From quenching or degreasing media.

No serious effect, either, from the tempering, and – 120°F deep-freeze operations through which these same trays must often go.

Strength, fabricability of Inconel alloy opens way to new operating economies

Wiretex Mfg. Co., Inc., Bridgeport, Conn., has used the excellent strength and fabricability of wrought Inconel alloy to design into these trays features that cut Fenn's heat-treating costs some 20%. These include:

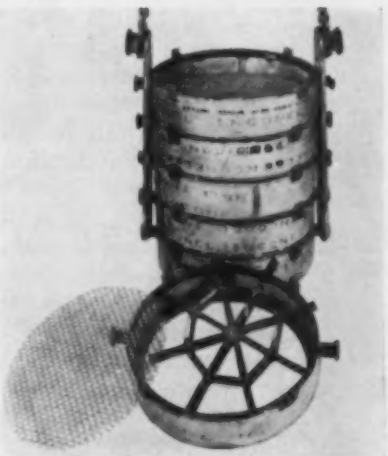
(1) A reduction in fixture weight that cuts heating time approximately 25%.

(2) An increase in allowable work load per tray over former trays of 30%.

(3) Improved stacking and lifting configurations speed materials handling.

The use of easily weldable Inconel alloy also improves repairability of the equipment, extends its life expectancy. There are two good ways to get the word about Inconel alloy fixtures: Your fabricator is one. The other is to write for the Inco bulletin, "Keeping Costs Down When Temperatures Go Up." *Registered trademark

The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.



"This shows you tray design. Walls are solid Inconel alloy rolled and welded. Removable Inconel alloy grid and woven screen rest on shoulder."

Inconel... *for long life at high temperatures* INCO Nickel Alloys

XXI

This is the twenty-first of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

How Alloy Steels Respond to Induction Hardening

In the now-popular induction-hardening process, steel is first heated above the transformation range by means of electrical induction, then quenched as required. Special equipment is needed, and heat is developed as follows:

High-frequency alternating current passes through a coil or inductor, with the result that a magnetic field is created in the coil. When the piece to be treated is placed in this field, it is heated rapidly by induced energy. With the various types of induction-heating equipment, the process is capable of surface- or case-hardening to various controlled depths; however, through-hardening can be obtained with certain alloy steels. Ferrous metals that respond well to induction hardening include numerous grades of both alloy and carbon steels, as well as hardenable stainless steel and plain or alloyed cast iron.

As a rule, when alloy steels containing no carbide-forming elements are heated by induction, the usual hardening temperatures can be used. But with alloy steels that do contain such carbide-forming elements as chromium, molybdenum, and vanadium, the hardening temperature must be increased if shallow cases are required and the normal effect of the alloying elements is desired.

Hardness obtained by the induction process is a function of the carbon content and prior structure, just as it is when conventional heating methods are used. Nevertheless, higher surface-hardness values for a given carbon content have often been noted in parts subjected to surface induction-hardening. The extra hardness may be as much as five Rockwell C points for steels of 0.30 pct carbon.

As pointed out previously, the induction method requires special equipment. However, it possesses several marked advantages, including speed of heating and cleanliness of operation. Pieces heated by induction are usually subject to a minimum of scaling and distortion. Moreover, induction-hardening equipment is very compact and therefore conserves floor space.

If you would care to know more about the induction hardening of alloy steels, you are invited to communicate with our technical staff. Bethlehem metallurgists have made a thorough study of the subject, including the many details of quenching and tempering. Call them if they can help you in any way. And remember, too, when considering sources of alloy steels, that Bethlehem makes the full range of AISI standard grades, as well as special-analysis steels and all carbon grades.

If you would like reprints of this series of advertisements from No. I through No. XX, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The first 20 subjects in the series are now available in a handy 36-page booklet, and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Introducing Handy
ALUMIBRAZE
A NEW METHOD FOR JOINING ALUMINUM
HANDY ALUMIBRAZE is a powdered aluminum-silicon alloy and flux mixture for use in salt bath brazing. It can be used to join complex aluminum assemblies and has been tested and plant-proved for two years.

Typical Alloys Being Brazed With ALUMIBRAZE

Old Designation	New Designation
2S	1100
3S	3002
52S	5052
54S	5154
61S	6061
62S	6062
63S	6063
66S	6066

A612 Casting
Pioneer 40E Casting
X2219 Casting

HANDY ALUMIBRAZE is manufactured by Handy & Harman under license from The Glenn L. Martin Company. Patent applied for.

ADVANTAGES: Cost savings are immediate through the reduction of complex jigs and fixtures. Placement of the alloy is rapid, simple and sure. Alloy is preplaced in exact amount required, precisely where needed. It stays put during the brazing cycle. Even heating minimizes the possibility of warpage. And the soundness of HANDY ALUMIBRAZED joints, their strength and their corrosion resistance are equal to or better than joints made with conventional forms of filler metal.

HOW IT WORKS: Mixed with water to form a slurry, HANDY ALUMIBRAZE is applied adjacent to the joints required to fill the joints and make fillets. Assembly is then baked at 1000°F to remove moisture. This leaves the brazing alloy powder firmly cemented to the aluminum surface, the flux serving as the cement. Assembly is then dipped in molten brazing salt. The flux cement itself has a higher melting point than either the brazing alloy or the brazing salt, but it is soluble in the molten salt bath. Thus, the brazing alloy is held in place even while melting until the cement has been dissolved by the molten salt. As the flux cement is dissolved away from the molten filler metal, the alloy runs into the joint capillary spaces and also forms a generous, smooth fillet. Send for Bulletin 23. It gives full details on this modern, cost-cutting development.

BULLETIN 23

gives you the complete Alumibraze Story. Send for your copy today.

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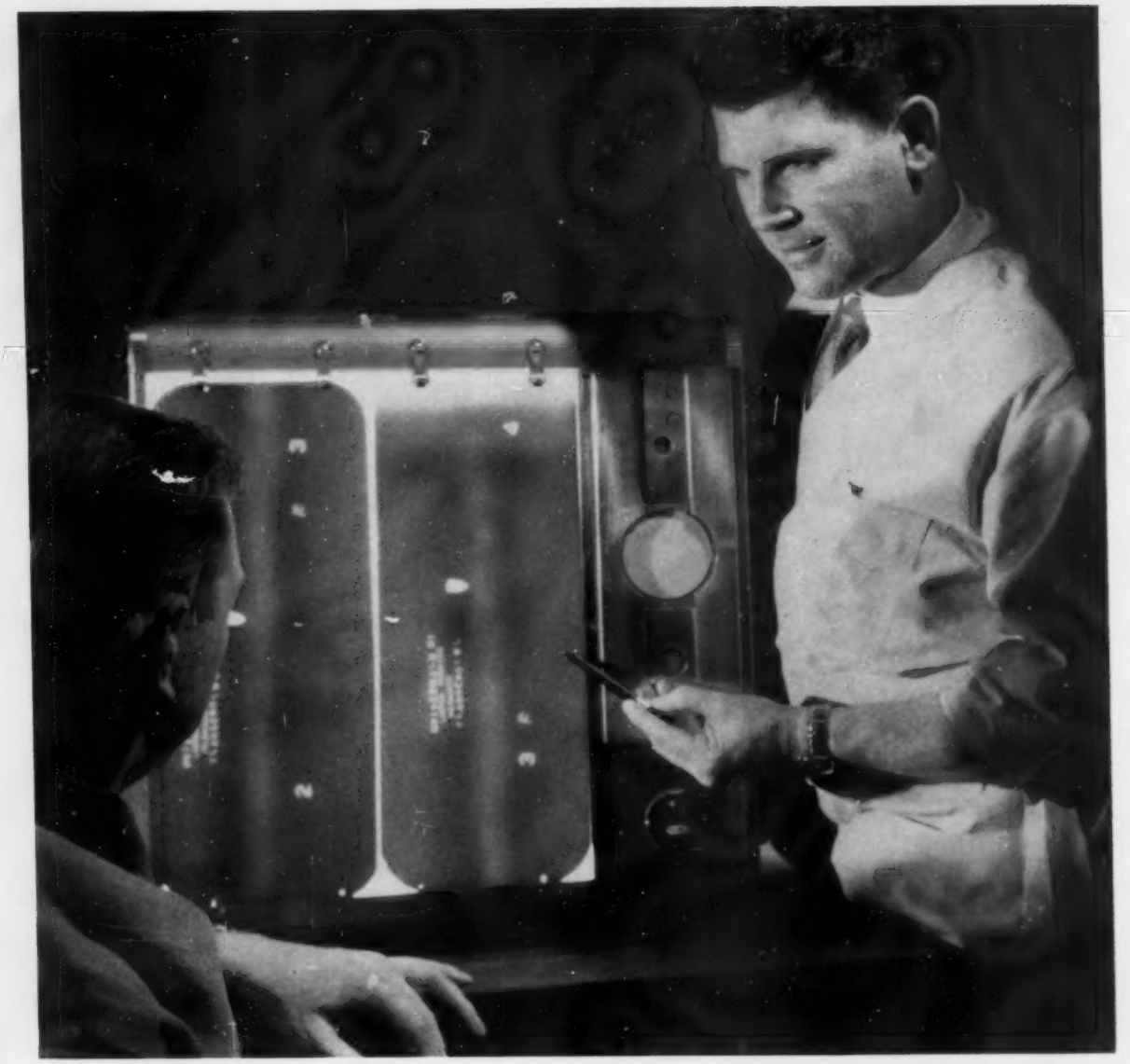

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Visit the KENNAMETAL* Exhibit...

Design Engineering Show, Booth 923, 2nd floor
New York Coliseum, May 22-23

See the KENTANIUM* Demonstrations

...how this titanium carbide PERFORMS at 2000°F

One of several demonstrations we will have at the Design Engineering Show in New York City will show the exceptional resistance of Kentanium to oxidation at elevated temperatures. (Note the accompanying report of a recent test.) This suggests how well Kentanium will perform at 2000°F. Come in and see this dramatic demonstration. It quickly demonstrates one of the many unique properties of Kentanium and may suggest applications where it can help you.

...see these other demonstrations

1 **THERMAL SHOCK:** Another demonstration will show the effect on Kentanium when first heated to 2000°F and then cooled to 300°F in approximately one minute. Be sure to see it.

2 **HIGH MODULUS:** This demonstration shows the high rigidity of Kentanium—approximately twice that of the hardest steel alloy. Kentanium has the highest stiffness to weight ratio of any material.

3 **WEAR-RESISTANT** properties of Kentanium while heated to a high temperature and subjected to severe wear conditions.

...and see these high purity (99.5%) metals and compounds

Columbium (Niobium)—powders, granules and bars
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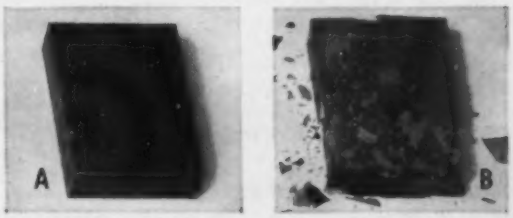

KENTANIUM unharmed at 2000°F while heat-resistant nickel-chrome alloy disintegrates

Here's proof of Kentanium's exceptional resistance to oxidation at high temperatures.

A square of K161B Kentanium and a similar square of well-known, heat-resistant 35 chromium-15 nickel alloy were exposed for 120 hours in an unsealed muffle furnace heated to 2000°F. The accompanying photographs vividly show how each piece was affected. While Kentanium (See "A") is still good for hours of exposure at high temperatures, the nickel-chrome alloy (See "B") has oxidized badly and has begun to disintegrate.

Combined with its high resistance to oxidation, Kentanium has great strength and resistance to corrosion.

These characteristics suggest how well Kentanium will perform in such applications as furnace parts, heat-treating fixtures, quench guide rings, turbine blades, nozzle vanes, bushings and other parts where strength at high temperatures, plus high resistance to oxidation, are factors.

C-30168

If you do not plan to attend the Design Engineering Show, send for copies of our "Characteristics" booklet No. 111-A and "Design" booklet No. 222. Write KENNAMETAL INC., Latrobe, Pennsylvania.

*Trademarks

See our catalog in Section 1b/Ke, Product Design File, Sweet's Catalog

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You save up to 75% with this new cleaner for castings

If you use an electrolytic salt bath to desand castings, you can make real economies with VIRGO® Electrolytic Salt, a new, yet well-established Hooker product.

You pay less for VIRGO Electrolytic Salt. Savings can be as much as 75% over comparable salts.

With this product, you remove sand, scale, graphite, and other surface impurities from iron and steel castings in 15-20 minutes. You get a chemically clean surface.

No acid dip. This VIRGO salt works the same as other electrolytic salts, in an 850-900° F. bath, at 6 volts or less. The process requires no acid, unless it is a prerequisite for subsequent operations.

The electrolytic action of the bath leaves casting surfaces resistant to rust; helps *keep* them clean while they await further processing.

To prove for yourself that VIRGO Electrolytic Salt can clean your castings—*for less money*—write us about submitting samples of your work for test cleaning. If you'd like technical data only, just check the coupon.

2 other specialized VIRGO products

Keep your process file up to date with the latest information on these other VIRGO metal cleaning compounds:

1. VIRGO Descaling Salt. For descaling titanium or stainless steel sheet, strip, wire, rods, tubes and other forms quickly, economically, without attacking the base metal.

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A mark on the coupon will bring you a technical data sheet that shows at a glance how much Hooker muriatic acid you need to make up solutions of various strengths.

The same sheet gives some good advice on the safe handling of muriatic acid, and the specifications of Hooker muriatic.

Even a quick glance at the specs is likely to convince you that the purest muriatic you can buy anywhere is "*Hooker White*" grade. Entirely free of arsenic and free chlorine, this grade contains no more than .003% sulfates, .0001% iron.

You'll discover that our *Commercial Grade* muriatic is only slightly less pure: iron, .0005%; free chlorine, a trace; sulfates, .003%; organic matter, .001%; arsenic, none.

Both grades are available for your use in rubber-lined tank cars in 18°, 20°, and 22° Baumé strengths.

How to cut degreasing costs

You may have wondered if there isn't some way to extend the time between degreaser cleanouts, to get more use from the trichlorethylene you buy.

Well, there is. You see, all trichlorethylene is protected by a stabilizer against heat, light, air, moisture, acids, and active metals such as aluminum.

During normal use, the stabilizers in some brands of trichlorethylene tend to "wear out" or become depleted. That's why you may have to add new stabilizer. Eventually, if stabilizer is not replenished, the bath will "go sour."

But—when you use NIALK® TRICHLORethylene in your degreaser, you *never* have to add fresh stabilizer! You stand a better chance of going a long time between degreaser cleanouts. Why?

NIALK (and *only* NIALK) has PSP—permanent STAYING power—in its neutral stabilizer. The stabilizer *can't* wear out during normal use. Even after repeated distillations, it's still active—protecting your parts against staining, keeping the bath from "going sour."

If you'd like to learn more about NIALK TRICHLORethylene and what it can do for your degreasing operations, just check the coupon.

Check items on which you'd like more information:

- ☐ VIRGO Electrolytic Salt
- ☐ VIRGO Descaling Salt
- ☐ VIRGO Molten Cleaner
- ☐ Caustic Soda
- ☐ Muriatic Acid
- ☐ NIALK TRICHLORethylene

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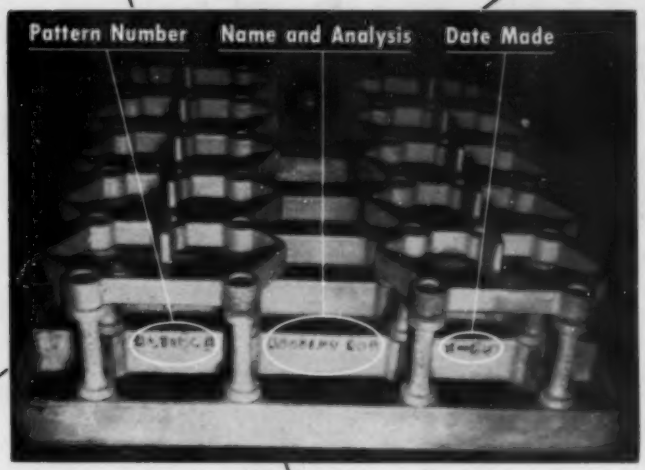

Here is proof positive for longer service life!

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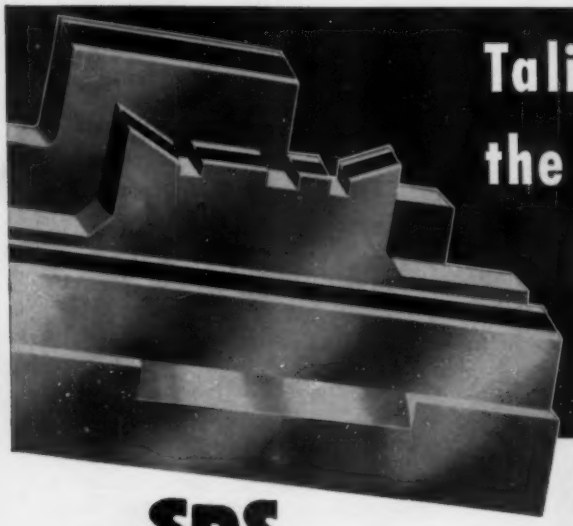

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world's largest producer of socket screws, has been a regular user of Talide-tipped centerless grinder blades for the past 10 years. SPS centerless grinders are equipped with super-hard Talide centerless blades, enabling millions of precision parts to be centerless ground without downtime for blade changing, regrinds or replacements. The Talide carbide wear strip is produced by us in ONE SOLID SECTION UP TO 100" IN LENGTH WITHOUT SEAMS. A solid carbide wear strip has been proven more efficient than shorter sections brazed or butted together because the possibility of marking or scoring the work is eliminated.

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A leading strip steel producer of razor blade, high-carbon, spring and stainless steel reports over 1200 coils were gang slitted with Talide knives compared to 15 coils with steel knives. More tonnage was produced in one regrind of the Talide knives than over the entire life of a set of steel knives. Burr-free, clean-cut edges produced with scrap rate practically eliminated.

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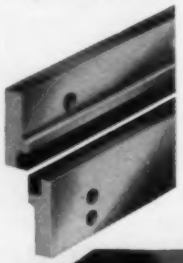

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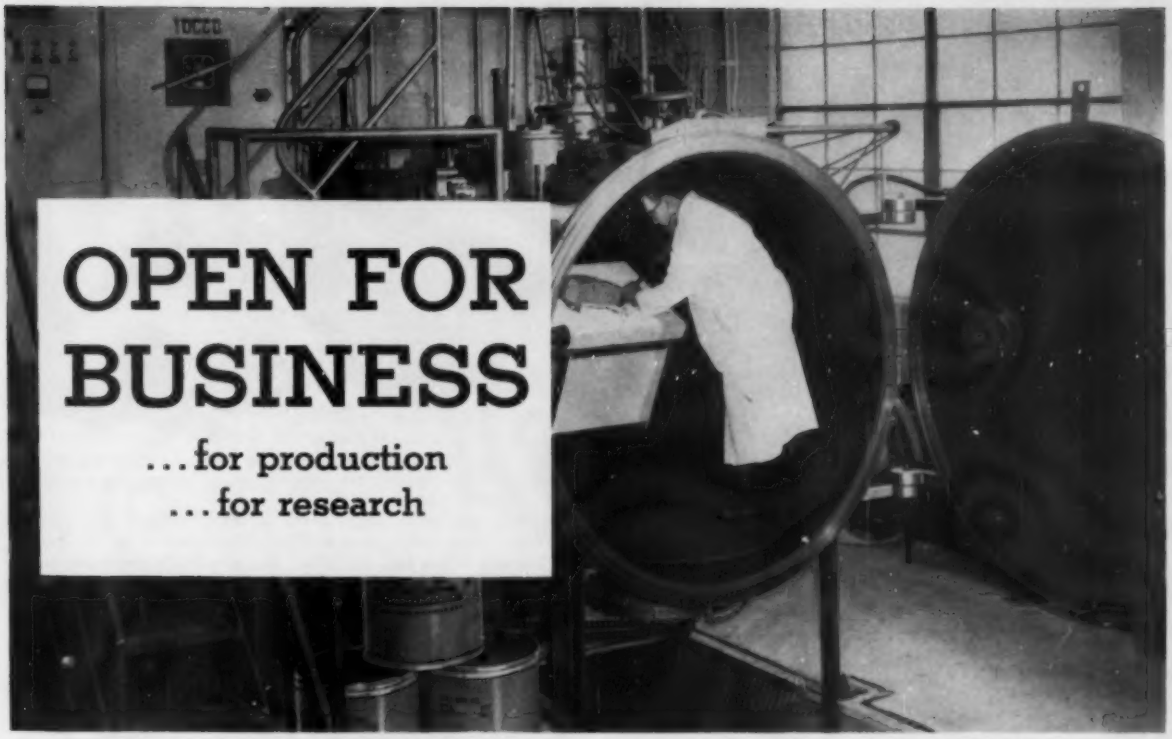

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Compact NMR-12 model (at right) is designed for continuous, heavy service at temperatures to 2800°F. It will conserve floor space in your laboratory or shop . . . cut operating expense . . . speed testing or production.

Specifications NMR-12 Setting space 12″ wide x 14″ high x 17″ deep. 3000° F. internal refractories. External blower for accelerated cooling. Transformer capacity 15 KVA at 110 volts, 30 KVA at 220 volts on the secondary. Can be equipped for any standard voltages, phases and frequencies.

Instrumentation: Optional, for simple temperature control, repetitive heating to any preselected temperature with or without adjustable holding time, or with complete program control.

Standard Harrop furnace models cover setting spaces from 7″ x 7″ x 9″ to 36″ x 36″ x 40″.

Special furnace applications demanding an unusual shape or size of firing chamber, variation in door opening, temperature range or other specific requirements will be designed and built by Harrop. Depend on Harrop's years of experience and engineering knowledge to solve your particular furnace problem quickly and economically.

Standard NMR-20 model (pictured below) 20″x 20″x 24″ setting space, temperature range to 2800°F, silicon carbide resistor heating elements, blower for accelerated cooling.

Standard instrumentation includes program controller, 6 tap switches and selector switch for manual or instrument control and blower cooling. Instrumentation can be varied to meet any requirement.

For non-obligating recommendation on the furnace for your particular need, send information on materials, temperature range, heat control and firing objectives to: Dr. Robert A. Schoenlaub, Technical Advisor.

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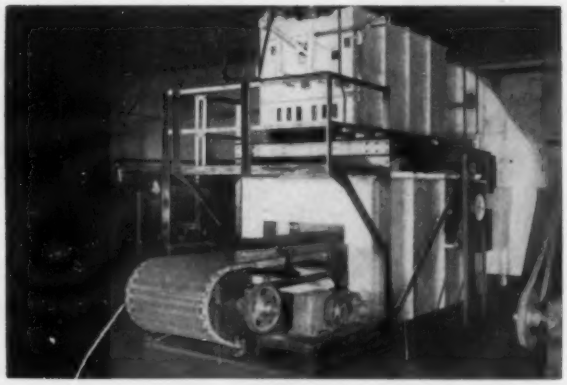

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Missile Metals . . .

Since 17-7 Cr-Ni precipitation hardened steels are being used to an increasing extent, much study is being given to their weldability. There is little difficulty in making a good-looking joint in sheet metal, but the microstructural characteristics of the weld metal are quite different from the parent metal. George E. Linnert, research welding metallurgist for Armco Steel Corp., Baltimore, Md., said that a small increase in chromium and nickel in the welding electrode will bring the weld metal nearly back into line and thus restore the tensile elongation. If the structure is to be heat treated after welding somewhat higher precipitation hardening temperatures are also required.

This interesting meeting concluded with a paper on conservation of nickel in high-temperature metals by E. E. Reynolds, associate director of research for Allegheny Ludlum Steel Corp., Watervliet, N. Y. The author said he had no objection to nickel – quite the contrary, he "only wanted to spread the wonderful stuff further". A potent means to conserve nickel in wrought stainless steels is the new Type 200 steels added to the list of standard analyses by the American Iron and Steel Institute, wherein about half the nickel is replaced by a little more manganese. Some valuable new alloys of this family have been developed in researches sponsored by the U.S. Air Forces.

The Type 200 Fe-Cr-Ni-Mn steels are primarily for corrosion resistance at atmospheric or moderately elevated temperatures. Further and considerable savings can be made in nickel as well as other critical elements in analogous alloys for service in the 1000° to 1500° F. range. These are being intensively evaluated in gas turbines, and indications are that they will be widely used in the future.

It appears that about 10% of manganese is required in high-temperature Fe-Cr-Ni-alloys for service at 1200° F. and 18% at 1500° F. Molybdenum is an important strengthener in these alloys, boron and nitrogen are hardeners, columbium and titanium are carbide stabilizers. Oxidation is controlled by proper additions of chromium.

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A new and better iron powder—Plast-Iron Grade D-280—is specially designed for producing high density sintered compacts. A modified electrolytic iron powder, Plast-Iron Grade D-280 develops a pressed density of 7.10 gms/cc at 50 tsi. Practically free of laminations. Working samples of this moderately priced new and improved pampered powder available on request.

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PM-10

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Division of
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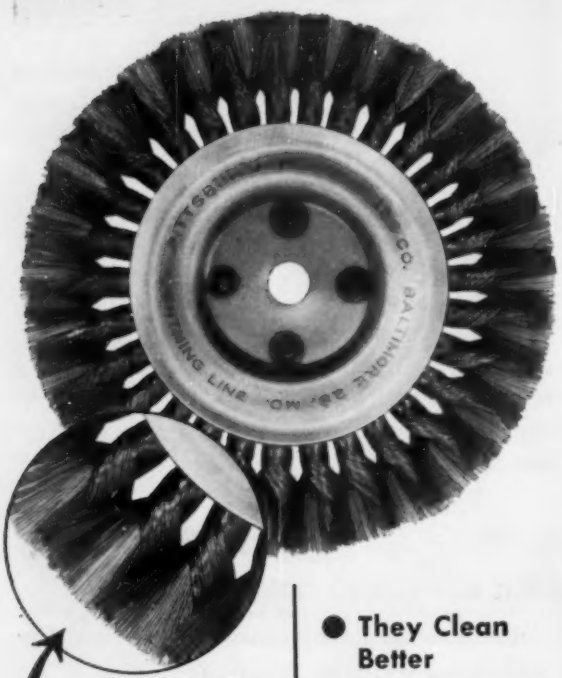

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● We have been engineering, designing and building brushes for a wide variety of industries for many years. Our long experience can save you time and money. Write Pittsburgh Plate Glass Company, Brush Division, Dept. MP-57, 3221 Frederick Avenue, Baltimore 29, Maryland.

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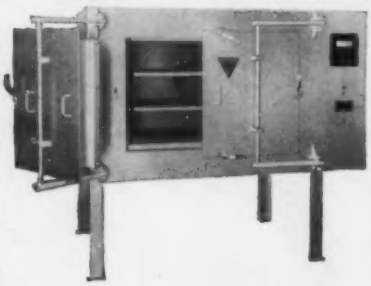

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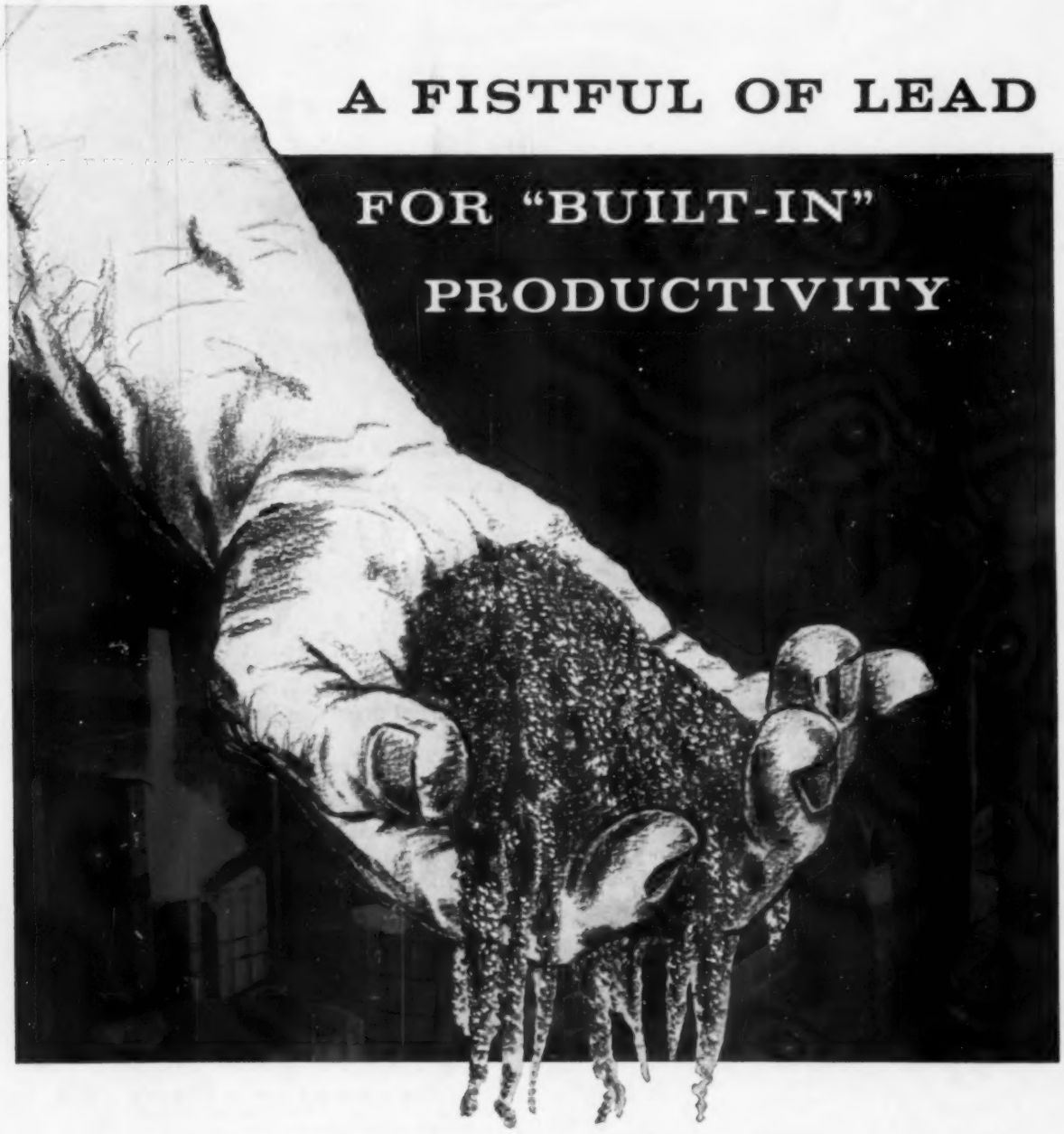

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